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ABSTRACT

The objectives of this study were to determine: (1) whether or not cognitive processes differ between advantaged and disadvantaged groups; (2) the capacity of pupil response to measure cognitive ability as compared to measurements of cognitive processes depending on verbal ability and environment; (3) whether pupil response can predict future academic performance; and (4) if differences and similarities found in cognitive functioning of advantaged and disadvantaged kindergarten children exist to the same degree in advantaged and disadvantaged high school students. Subjects tested were 64 kindergarten children and 60 high school students from advantaged and disadvantaged backgrounds. Results indicated that pupillary dilation is directly related to cognitive activity in a number of situations requiring vested effort on the part of the subject at the high school and kindergarten levels. (Author/EK)

FINAL REPORT

DIFFERENCES IN THE SIZE OF THE PUPIL OF THE EYE AS A MEASURE OF LEARNING CAPACITY AND THE LEARNING PROCESS IN KINDERGARTEN AND HIGH SCHOOL STUDENTS

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INTRODUCTION

Changes in the size of the pupil of the eye have, in the past decade, been related to a number of phenomenon, such as interest (1), attitude (2), and mental activity (3, 4, 5). That pupil diameter is not always a function of existing light conditions is not a recent finding, and was clearly related to emotional states by Darwin (6). Anecdotally, it is evident that in the 16th and 17th centuries the dilated pupils of a woman were considered to enhance her appeal to men, since the drug Bella Donna (literally translated "Beautiful Woman") was commonly used by women to artificially dilate their pupils. And, nearly 70 years ago changes in pupil size were reputed to occur when subjects were instructed to imagine entering a dark cave or going out into an open area where the sun is shining on snow covered ground (7).

As this area of research has developed, studies involving this technique were categorized as "Pupillometric" studies. The distinction between pupillometric studies and research on reflexive changes of the pupil of the eye is an important one: Traditional studies of the pupillary reflex involve changes of pupil size in relation to changing external light conditions (or classical conditioning of the pupillary reflex, where changes in illumination serve as the unconditioned stimulus); pupillometrics involves changes in pupil size which are completely independent of changes in light intensity in the environment. In fact controls are used to insure that light conditions are kept uniform. In general, the pupillary reflex is under the control of the parasympathetic branch of the autonomic nervous system while the change dealt with in pupillometric research is due to sympathetic functioning. In a simplified way, it is almost as though the eye retains its early embryonic relationship with the brain, and reflects cortical activity in a way which is available for empirical observation.

Even though there was ample evidence that pupillary changes were related to conditions other than light intensity, there was little systematic investigation of this phenomenon before 1960. The initial study of Hess and Polt (1) report differences in pupil size between male and female subjects while viewing five slides projected on a screen. It was found that the women's pupils dilated while viewing a picture of a baby and a picture of a man in a bathing suit, while the men's pupils dilated when viewing a pin-up picture of a girl. In this study, the pupil response was interpreted as an indication of the subject's interest in the stimulus material being viewed by the subject.

During the following years studies were published by Dr. Hess and his associates dealing with the relationship between pupillary activity and mental activity (3), responses of heterosexual and homosexual males to pictures of males and females (9), the pupil response to gustatory stimuli (8), the pupil response to visually presented words (10), and the pupil

response as a measure of attitude and attitude change (2). In addition, much research of a preliminary nature was carried out in Dr. Hess's laboratory which was not published (the Principal Investigator was involved in much of this research from its inception in 1960 to the end of 1966, when he assumed his present position at Temple Buell College). In these studies pupil changes were obtained to stimuli in all sensory modalities: visual, auditory, taste, olfactory, and tactile.

The aspect of pupillometrics which is of particular relevance to the present research is the relationship found between pupillary dilation and mental activity, which seems to indicate that changes in pupil size serve as a direct measure of cognitive functioning. This phenomenon was reported by Hess and Polt in 1964 (3), where it was demonstrated that the magnitude of dilation was positively correlated with problem difficulty. (The mean increase in pupil size while mentally solving the problems: 7 x 8, 8 x 13, 13 x 14, and 16 x 23 was: 10.8%, 11.3%, 18.3% and 21.6% respectively.) Similar findings were reported by Kahneman (4,5). Two unpublished studies by Polt (11, 12) utilize this phenomenon: one dealing with anxiety arousal and pupil dilation and the other a study of pupillary activity where two conflicting responses are simultaneously activated (constriction, elicited by a flash of light while the subject's pupils are dilated during mental problem solving).

Objectives of the Present Research. The fundamental problem toward which this research was directed was the feasibility of using the pupil response, i.e., changes in the size of the pupil of the eye, as a differential measure of cognitive functioning in middle-class and culturally disadvantaged populations at the kindergarten and high school levels.

Within this context, four primary research objectives were delineated in the initial research proposal.

1) To determine whether or not cognitive processes, as measured by pupillary dilation, are basically different in disadvantaged populations, as compared to more advantaged populations, and how significant differences are which might exist between populations. This objective was basically intended to determine whether different patterns and magnitudes of pupillary changes existed among the two populations at the two age levels.

2) To determine the capacity of the pupil response to measure inherent cognitive ability as compared to the measurements of cognitive processes which depend on verbal ability and reflect the environmental background of the individual. To achieve this objective, a comparison is required between verbal and pupillary scores in the various populations. It was assumed that the results of such a comparison would answer the question of whether verbal and pupillary scores are measuring the same or different levels of cognitive functioning.

3) To determine whether the pupil response, as an indicator of cognitive ability, can predict future performance in an academic situation. Since previous research had indicated differences in the magnitude of the pupillary response related to problem difficulty and individual mathematical apptitude (3, 11) it appeared that if the pupillary response was successful in differentiating subjects, either within or between groups, that the pupillary response might function as a predictor of later behaviors which depend heavily on cognitive activity.

4) To determine if differences and similarities found in the cognitive functioning of kindergarten children from disadvantaged and middle class backgrounds exist to the same degree in groups of high school students from the disadvantaged and middle class environments. Analysis in terms of differences and similarities in both the verbal and pupillary scores were included because typically studies with middle-class and disadvantaged populations have indicated that with verbal scores, if scores at kindergarten age are used as a baseline, discrepancies between populations increase with age.

Extent to which Objectives were met in the Present Study. A large part of the data generated by this study is relevant to objective #1. Based on the extensive tests for cognitive functioning employed in the present research extensive differences were not found in cognitive functioning at either age level.

In regard to the second objective given above, the pupillary data would indicate that measurement of cognitive activity is consistent with previous research in this area. If a tentative statement were to be made as to whether the pupillary data was a reflection of inherent or culturally determined cognitive ability, failure to find differences between groups would support the hypothesis that inherent ability, which did not differ between groups, was being measured. Because each subject was run on a number of tests, a meaningful analysis of individual scores was not feasible. This, perhaps, constitutes a weakness in the original design of the study.

The large number of scores obtained from each subject precluded the type of analysis which would have permitted drawing conclusions about the predictive value of pupillary activity for later academic performance. Individual correlations of pupillary scores with later academic success would have required going to a computer with the data. Again, this reflects a weakness in the original study design.

The fourth objective was met in the present study. The tentative conclusion, based on the present data, is that in the present populations tested there were no basic response differences at either age level.

METHOD

Kindergarten Subjects. Sixty-four kindergarten students were tested in the Spring of 1968. These were broken into three groups: middle-class Caucasian (KMC), N = 22, mean age = 5 years, 10 months; disadvantaged Caucasian (KDN), N = 20, mean age = 5 years, 11 months; and, disadvantaged non-Caucasian (KDNC), N = 22, mean age = 6 years, 1 month. The disadvantaged non-Caucasian consisted of nine Negro and 13 children of Mexican-American background. Each of the three groups contained an equal number of male and female subjects. Students were run in elementary schools in two suburban Denver school districts, Mapleton and Aurora. The majority of the subjects had pre-school experience. Fifteen of the middle-class subjects had attended nursery school, while 34 of the disadvantaged subjects had been in a Head Start Program. The disadvantaged subjects could not be divided into experienced and inexperienced groups of equal size because of insufficient subjects who had not had Head Start experience in the schools available to the Principal Investigator from which to select subjects. An attempt was made to equate pre-school experience in the middle-class subjects, though in this group slightly fewer had previous school experiences (68% vs. 81%).

High School Subjects. A total of 60 high school subjects were tested during the last two months of their junior year (42) or within one month after the end of their junior year (18). These subjects were divided into four groups of 15 subjects each: disadvantaged Negro (HDN); disadvantaged Mexican-American (HDM); middle-class Caucasian I (HMCI); and middle-class Caucasian II (HMCII). The 30 Caucasian subjects were divided into two groups for control purposes: to determine the reliability of both pupil and verbal scores with groups of this size when drawn from the same population. Slightly more males than females were tested, with groups HDN, HDM, and HMCII containing eight males. Group HMCI contained seven males. Subjects were drawn from Upward Bound students on the Temple Buell College campus during the summer of 1968 and from the Aurora school district. A common factor among the high school subjects was that they were planning to enter college. This was a requirement for subject selection.

For both kindergarten and high school subjects, classification into disadvantaged and middle-class groups was determined by the geographic location of the home, father's occupation (where the father was present in the home) and programs in which the family was involved, such as ADC, Upward Bound and Head Start.

Apparatus. The apparatus used in this study was one designed at the University of Chicago by E. H. Hess for pupillometric research.

The basic apparatus consisted of a formica covered box, 24" long, 19" high and 14" wide, with two adjustable front legs. At the front of the box

was an opening 6" x 3½" into which was set a rubber face piece. At the rear of the box, 23" from the eye of the subject, was a rear projection screen, 11" x 11½".

The inside of the box was painted flat black. A standard 25-watt red bulb in an aluminum reflector provided the illumination for photographing the eye. This bulb was located 7½" from the subject's left eye. On the left wall of the box was a 2½" x 3½" front surface mirror in an adjustable aluminum mount, 9" from the subject's left eye. This mirror reflected the image of the eye into the lens of a 16mm. Bolex camera, mounted on the right side of the apparatus. The camera and mount were on the outside of the apparatus, and the 100mm. lens equipped with 30mm. of extension tube protruded into the apparatus, so that the lens was 6½" from the mirror. The total lens to eye distance was 15½".

The camera mount also held a 15 RPM Bodine motor, which is attached by a shaft to the camera drive, and advanced the film at a rate of 1-frame-per-second, with a ¼ second exposure for each frame. The film used was Kodak High Speed Infra-red. With this film and exposure time, the lens was stopped down to f 8.

There was also a standard 40-watt white bulb in the box. This was put on only during the pre-run period, when additional light is required to center the subject's eye in the view-finder of the camera.

The projector used with the apparatus was Kodak Carousel 35mm. projector with remote control cord. Both the power cord and the remote control cord are plugged into the apparatus. This made is possible to turn the projector on and off from the control panel of the apparatus. The projector was connected to a 10 second timer, so that it could be automatically advanced every 10 seconds while the subject was being run.

The apparatus was equipped with a frame counter driven by a belt from the camera drive shaft. This made it possible to record the precise frame at which events occurred (i.e., when problems and answers were given) in series where stimuli were not presented automatically at 10 second intervals. Blank frames were exposed between runs to facilitate identifications of runs on the processed film.

Procedures, Kindergarten. The same procedures were used for all subjects. Each subject participated in three experimental sessions which were scheduled one week apart. In a few cases, because of absence from school on a scheduled day, there was a two week interval between test sessions.

Session I. Session I was begun with a simple discrimination involving only a verbal response. The subject was presented with a series of cards, one cord at a time, on which there was either a three inch or a two inch square.

The color of the square was either red and blue, with each size square randomly assigned to one color on half the trials. The only relevant dimension, however, was size. Half the subjects received a penny reward for choosing the large square, half for choosing the small square. Each subject was run until he had made 10 correct responses.

Selection of this task as the initial contact served to get the subject acquainted with the experimenter in a positive situation. Additionally, learning this discrimination fit into the over-all experimental design by providing a learned task for later study in regard to the pupil response.

The subject was then seated in front of the pupil apparatus and given instructions about positioning the head, not moving unless necessary and looking at the slides. The first two sets of slides consisted of a series of five geometric forms, each preceded by a matched control slide.

In addition to studying the response to forms, these series also were designed to provide information about the perception of novel stimuli. One series consisted of four squares followed by a circle. The second series consisted of four upright triangles followed by an inverted triangle. Previous research with these stimuli has indicated that the response to the last form in a series might serve as a measure of perceptual sophistication (13). Half of the subjects were shown the square-circle series first, half the triangle-inverted triangle series first. The subject had his head in the apparatus for one minute and 40 seconds for each set of slides. A one-minute rest period was given between sets.

After another rest period the subject was shown a series of five numbers. The numbers 8, 3, 9, 4, and 7 were presented, each preceded by a control slide matched in brightness to that stimulus slide. After the pupil response to the numbers was recorded, the subject was shown the same series a second time. The subject was instructed that this time when the number came on he would be asked, "What number is that?" when the number came on the screen. He was further instructed to keep looking at the number when he answered and that he should not move his head or look at the experimenter. A record was kept of the subjects verbal identification. The subject was in the apparatus for one minute and 40 seconds for each presentation of this series.

The purpose of this series of slides was to determine the subject's reaction to the numbers as measured by the pupil response, for analyses in relationship to the degree of familiarity with the stimuli, and to determine if individual or group differences existed in the pupil response where the subject was or was not able to correctly label the number.

After completion of the number series the subject was asked to verbally identify the three forms used in the previous series. He was also shown the numbers which he had not identified in the apparatus and asked to identify these numbers. The latter procedure was to determine whether lack of

The third series in Session II consisted of pictures of three objects. A pair of pliers, a can opener (the type with two handles which is wound around the edge of the can lid) and a Kennedy half-dollar. The same procedure was used as in the color series. After obtaining the pupil response to the objects, the response was recorded while the subject was asked to identify the object. Each presentation lasted for one minute.

The fourth series in Session II was a color discrimination, with which the subject had no previous experience. The stimulus slides consisted of a brown square and a green square against a gray background. Each stimulus slide was preceded by a match control slide. The subject was told, "Now you are going to play another game for pennies. This time you will see pictures of different squares and I want you to do the same thing you did before: lift this arm (E touches right arm) if you want the square on this side; lift this arm (E touches the left arm) if you want the square on this side. Each time you are right I'll drop a penny in the glass for you."

Eight trials were then given, with a break between the fourth and fifth trial. Each color appeared an equal number of times on the left and on the right. This series took two minutes and 40 seconds exclusive of the break. Both the square chosen and the pupil response were recorded.

After this series the subject was shown the slides from the color series and object series which he had missed and asked again to identify the color or object. The session was then terminated and the child returned to his classroom. This session took approximately 15 minutes.

Session III. Session III started with recording the pupil response as the subject answered three questions. An "X" was projected on the screen as a fixation point while answering the questions.

The following instructions were given: "The first thing I'd like to do this morning is ask you some questions. Do you see that "X" on the screen? (E points into apparatus). Just keep looking at the "X" until we finish. When you answer the question, keep looking at the "X", don't look at me. Is that clear? All right, put your head against the cushion, and in a few seconds I will ask the first question."

The frame counter was previously set at "0" and Question 1, "What is your name?" was asked at frame 15 (after 15 seconds). The frame at which the answer was given was recorded and the second question, "What is your teacher's name?," was asked 15 seconds after the first answer had been given. The frame at which the second answer was given was recorded and the third question, "What is your best friend's name?" was asked 15 seconds after the second answer was given. The frame at which the third answer was given and recorded and the pupil response was recorded for another 15 seconds before the run was terminated. If a question was not answered within 20 seconds the next question was given, or in the case of question #3 the session was terminated. This run took

identification in the apparatus was due to an actual inability to label the number or to a possible factor related to the experimental situation.

Session I took approximately 20 minutes for each subject.

Session II. Session II began with the size discrimination which the subject had been trained on during Session I. This time the subject was placed in the apparatus and shown a series of slides which had been made of the stimulus cards containing the colored squares used in Session I. Each stimulus was preceded by a matched control slide.

The subject was told that he was going to play the same game for pennies which he had played last week, but that we were going to play it another way, and that he would be shown pictures of the squares instead of the cards. The first stimulus slide was put on the screen and the subject was instructed to rest one arm on each side of the apparatus. The experimenter pointed to the square on the right and told the subject, "If you want to pick the square on this side lift this arm." (E touches right arm). The experimenter then pointed to the square on the left side and told the subject, "If you want to pick the square on this side, lift this arm." (E touches subjects left arm). The instructions continued, "Now, every time you are right I'll drop a penny in this glass for you like this." (A penny is dropped into a glass on the table behind the apparatus with an audible sound). "Do you understand?" If the subject said no, or had a question the procedure is clarified.

The subject was then shown the series of five control and stimulus slides. Each time a correct response was given a penny was dropped in the glass. The same square was positive which had been positive during the previous session.

The subject's choice was recorded but the pupil was not photographed for this set of slides. Photographing of the eye was omitted because of possible problems which might arise in the subject's learning the new procedure for selecting the appropriate stimulus. With the attention devoted to the new procedure there was also a possibility that the pupillary activity might not be a true measure of the response to the stimuli per se.

In addition to adjusting to the new procedure this provided a chance to further reinforce this discrimination to insure a high level of learning. This five trials took one minute and 40 seconds.

The second series was a set of three colors (green, red, and blue). The patch of color was presented against a medium grey background. A control slide matched in brightness preceded with each stimulus slide. This series was presented twice. On the first presentation, the pupil response alone was recorded. On the second presentation the pupil was photographed as the subject verbally identified the colors. Each presentation took one minute.

approximately one minute and ten seconds.

After answering the questions the subject was given a new discrimination. The stimulus slides for this series were composed of ink drawings of two objects (see Appendix 1.). Four of the eight slides showed a doll and a pencil; the other four a flag and a box. Each type of slide appeared twice in every four trials with each object appearing twice on the right and twice on the left in every four trials. For each subject the first slide seen showed the doll and pencil, the second the flag and box. For half the subjects the doll and box were positive, for half the pencil and flag were positive.

The subject was given the same instructions as for the previous discrimination except that he was told that he would see pictures of two things that he hadn't seen before, instead of being told he would see two squares. A break was given after the fourth trial. Both the subject's choice and pupil response were recorded. This series took two minutes and 40 seconds, exclusive of the break.

The next series in Session III consisted of a set of four stimuli patterned after Street-figures (see Appendix 1.). Identification of the picture requires mentally filling-in of missing lines and parts for complete closure. Each stimulus slide was preceded by a matched control slide and the pupil was photographed during this series which took one minute and 20 seconds.

The last series in Session III consisted of a repetition of the five trials on the large and small, blue and red squares on which the subject had been trained on Session I and tested on Session II.

The subject was given the following instructions: "Do you remember the game we played last week with the blue and red squares? (pause for answer) Fine, we are going to play the game again now. When the squares come on the screen, you raise your hand for the one you want, and when you are right, I'll drop a penny in the glass, O.K.?" On this presentation the pupil response was recorded as well as the subjects choice. This series of five stimulus and control slides took one minute and 40 seconds.

After this series had been completed the subject was shown the slides used in the previous series (the Street-type figures) and asked if he knew what that was a picture of. The verbal response was recorded.

This ended Session III and the subjects participation in the experiment.

Procedures, High School. Each subject was tested in two sessions of 20 minutes each, which were scheduled one week apart. The same procedures were used with all subjects.

Session I. The subject was seated before the apparatus, with the first

control slide projected onto the screen. He was told that he would be shown a series of pictures and that every other slide would be identical to the one he was now looking at. He was then instructed to look at the numbers in order each time he saw this slide. E then pointed to each number, saying, "Look at the one, two, three, four and then look at the five until the slide changes." The subject was then told, "The other pictures will show a red square and a blue square, one large and one small. One square is correct and one incorrect. Each time you pick the correct square you will be rewarded with a nickle, which I'll drop into this glass (E drops a nickle into a glass). At first you will have no idea which is correct, so just take a guess. When we start, put one hand on each side of the box, and lift your right hand if you want the square on the right side, and your left if you want to choose the square on the left side. Do you have any questions?" If the subject had no questions, he was asked to put his head against the cushion of the face piece, the mirror was adjusted to center the image of the eye, the top of the apparatus closed and the camera and timer activiated simultaneously.

The subject was then given five trials on the same discrimination problem presented to the kindergarten children, where two squares were varied in color (blue or red) and size. As with the kindergarten children, the relative dimension was size, with half the subjects reinforced for selecting the large square and half reinforced for selecting the small square.

This series took one minute and 40 seconds.

The second series in Session I involved mental solving of multiplication problems. A slide with an "X" on it was projected on the screen and the subject was told to keep looking at the "X" while he was asked to solve multiplication problems. The subject was further instructed that as soon as he had solved the problem, he should give the answer, then forget that problem and wait for the next problem.

The first problem, 7 x 12 was given after the subject had been looking at the "X" for 15 seconds. The frame at which the answer was given was recorded, and 15 seconds later the second problem, 8 x 16 was given to the subject. The frame at which this problem was answered was recorded, and 15 seconds later the third problem, 13 x 17 was given to the subject. If a problem was not answered in thirty seconds the run was terminated (this only occurred with the third problem).

The average time for this series was 1 minute and 30 seconds.

The third series in Session I consisted of recording the pupil response to the four Street-type figures which had been presented to the kindergarten children. Each picture was preceded by a control slide matched in brightness to the stimulus slide. The subject was instructed to look at the numbers in order on the control slides and to look at the stimuli slides as he wanted to.

This series took one minute and 20 seconds.

The fourth series in Session I was an "anagram" type of problem solving where the task of the subject was to spell a word with a set of letters presented visually. The series consisted of three sets of letters preceded by a matching control slide.

The subject was told that he was to look at the control slide in the same way that he had before, and that following the control slide he would see a row of letters on the screen and his task was to spell a word with these letters.

Instructions continued, that as soon as he told the "E" what the word was, or after 20 seconds if he had not gotten the word, another slide with numbers would come on and he was to forget the last word and wait for the next set of letters.

The first control slide was on the screen for 15 seconds, followed by the letters, "olop", a letter combination which could spell "loop," "pool" or "polo." As soon as the subject responded, the second control slide appeared and the first response and the frame at which the response was given was recorded. After 15 seconds, the second set of letters, "rownb" was projected. If the subject did not respond in 20 seconds the third control slide was put on the screen and a record was made of the frame at which the third control slide came on. If the word was identified, the third control slide was projected and the second response and frame of response were recorded. After 15 seconds, the third set of letters, "ictano," were projected on the screen. The run was terminated when this word was identified or after it had been on the screen for 20 seconds without being identified.

This series took approximately one minute and 30 seconds.

After the completion of the fourth series, the Street-type figures shown in the second series were projected and the subjected was asked to identify the objects. The verbal response was recorded, but as with the kindergarten children, no pupil measure was taken.

The subject's next appointment was confirmed and the session was completed.

Session II. The first series presented in Session II was a second discrimination problem. This involved complex Chinese figures taken from Hull (14). Two pairs of figures were used, with one figure in each pair correct for half the subjects. Instructions were similar to those given for the first discrimination with the subject told that in each pair one figure would be correct, that each time he was he should raise his hand for the one he wanted to choose and that for each correct response he would receive a nickel. Eight

trials were given the subject, with the sequence of pairs: 1, 2, 2, 1, 1, 2, 1, 2.

The eight stimulus and control slides in this series took two minutes and 40 seconds, with the pupil response recorded during the entire series.

The second series in Session II consisted of pictures of objects, with some duplication of the series of objects shown to the kindergarten subjects. This series consisted of a pair of wire strippers, a can opener, a Kennedy half-dollar and a resister. A matching control slide preceded each stimulus slide.

After the first presentation, the subject was told that he would be shown the pictures a second time, and that he would be asked what each object was. If he could not identify the object, the subject was instructed to answer, "I don't know."

The pupil response was recorded on each presentation. Each presentation took one minute and 20 seconds, with a break of approximately 30 seconds given between presentations.

The third series in Session II was one which required the subject to find a "hidden figure" in the total stimulus complex of a projected slide. The object to be located was printed below the picture (see Appendix 1.).

The subject was given the following instructions, "Now we are going to do something different. You will see the slide with the numbers, and then a drawing. Below the drawing will be printed the name of something which you are to find in the picture, such as the word 'dog.' When you have found the object, tap your right hand on the table. In a few seconds a slide with the numbers will come on, followed by another picture. Each time the numbers come on, look at them in order. Look at the other pictures any way you want to. If you don't find the object in 30 seconds, we will go to the next one. Any questions?"

If there were no questions the subject put his head against the face piece, the mirror was adjusted and the session started.

After the control slide had been on the screen for 15 seconds, the first stimulus slide was put on the screen. The frame at which the object was found was recorded and the slide remained on the screen for 15 seconds longer. The second control slide was then projected, followed by the second stimulus slide. If the subject had not indicated he had found the object in 30 seconds, the series was ended. Where the subject did find the object, the frame at which he had indicated finding the number was recorded, and 15 seconds later the series was ended.

This series took approximately one-minute and 15 seconds. At the end of the series, the subject was asked what number he had seen in the second stimulus slide.

The last series in Session II consisted of four Street-type figures which were more complex than those shown the kindergarten subjects (see Appendix 1.). As with the other series, each stimulus slide was preceded by a matched control slide.

This series took one-minute and 20 seconds. At the end of the series, the subject was shown the stimulus slides and asked what each looked like to him. The verbal response was recorded.

At the end of Session II, the subject was given the money he received for the discrimination task and cautioned not to tell anyone about what he had done, since there were still others to be tested.

Treatment of Data. The raw data was in the form of exposed frames of 16mm. film. The developed film was projected off a mirror onto a rear-projection screen set into a table-top. The mirror was set in a stand underneath the table, providing a clear image for a measure seated at the table. An L & W Single Frame Projector was used for analysis, with the film image enlarged 17 times when it was projected on the table-top screen.

Two assistants worked together in measuring the size of the pupil. One measured the diameter of the pupil on each frame of film with a millimeter rule: and verbally gave the measurement which was recorded on a data sheet by the second assistant. The measurers periodically switched positions, although all film for a single subject was measured by the same assistant.

A percentage change for each stimulus was arrived at by obtaining the percent difference between a stimulus period and the preceding control period. (For example, if the mean pupil size to a stimulus was 77mm. - reflecting the magnification of the film when projected - and the mean pupil size during the preceding control period was 70mm., the response to that particular stimulus would be plus 10%).

In a series where slides were not presented for 10-second periods (such as mentally solving of multiplication problems or the anagram series) the record of when each problem was given and answered, as recorded from the reading on the frame counter, makes determining at what point in the series the various events occurred a simple matter. Following the procedure of Hess and Polt (3), in these series a comparison was made between the mean pupil size during the five frames before a problem was presented and the mean pupil size for five frames at the peak of dilation during the time the problem was being solved. The mean of the peak frame and the two frames bracketing it were used for this measure. The percent change was then computed for the size of the pupil at the peak during problem solving vs. the size of the pupil immediately before the problem was presented.

All results represent changes in percent during a stimulus or problem solving period as compared to a control period or pre-problem level, as outlined above.

Brightness Control. Changes in pupil size were measured under two conditions: 1) comparisons between a control slide and a stimulus slide; 2) comparisons between the size of the pupil before a problem was given and while the problem was being solved.

In the second situation, it was a simple matter to control for brightness. The subject kept his eyes on a fixation point on the screen during the entire run, so that there were never any changes in light intensity in the experimental situation.

Where slides were used, brightness control was accomplished in three ways (to ensure that pupil changes were not due to brightness differences between the stimulus and control slide or due to looking at areas of widely differing brightness within the same slide).

First, all areas of the stimulus slide were checked with a Honeywell-Pentax Spot Photometer. Where there was a difference of more than two units in the brightness of any areas of the projected slide, the slide was rejected for use. In this research, this was no particular problem, since the material on the stimulus slides was fairly homogeneous.

Second, the over-all brightness of a stimulus slide was measured at the lens of the projector with a Luna-Six light meter. A control slide was then selected for that stimulus slide which was equal in over-all intensity. This ensured that while viewing these slides the total light flux in the apparatus was equal for the stimulus slide and the preceding control slide, against which the comparison in pupil size was made.

Third, care was taken that all slides within a series were fairly equal in brightness. This was also accomplished by using readings at the projector lens taken with the Luna-Six light meter.

RESULTS

The results of this study will be presented in four sections, corresponding to the four categories of problems presented the subjects. These categories are: 1) Discrimination problems; 2) Mental problem solving; 3) Presentation of objects; 4) Presentation of Street-type figures. Both the verbal and pupillometric data will be presented in each section. Tables summarizing the data appear at the end of the results section.

Verbal and Pupil Data for Discrimination Problems. The data presented in this section includes three problems presented to the kindergarten subjects and two problems presented to the high school subjects.

There were no appreciable differences in the verbal responses on the discrimination problems (i.e. correct responses).

The correct responses for the three kindergarten groups for the green-brown discrimination were: Group KMC, 79.25%; Group KDC, 75.25%; Group KDNC, 77.5%. Percent correct responses for the discrimination involving two pairs of ink drawings were KMC, 79.75; KDC, 82.25; KDNC, 76.25. The percent correct response for the ten trials on the blue and red squares after initial learning during Session I, was 82% (KMC), 88% (KDC) and 76% (KDNC) for the five trials on Session II and 86% (KMC) 94% (KDC) and 84% (KDNC) for the five trials during Session III, when the pupil response was recorded for this discrimination.

For the high school subjects the percent correct responses for the red and blue squares were HMC I, 74.8; HMC II, 72.2: HDM, 76.0; HDN 78.4. This was the mean response for five trials, with the response on Trial I at approximately 50%, since the subjects were simply guessing as to the correct stimulus on this trial. The greater difficulty of the problem involving the Chinese figures is reflected in the lower scores for the eight trials on this discrimination. The mean percent correct responses were 64.5, 66.5, 63.25 and 64.0 respectively for groups HMC I, HMC II, HDM and HDN.

Except for the final block of five trials for the kindergarten subjects on the discrimination involving the blue and red squares (where a high level of learning had been reached on previous sessions) each discrimination showed an increase in correct responses with each successive trial during a particular discrimination.

The pupil data for the discrimination problems is summarized in Tables 1 and 2. There were no significant differences between groups for either the high school or kindergarten subjects. (Mann-Whitney U-test). However, several differences do emerge between populations and between problems. 1) Mean pupil size is significantly lower for the kindergarten subjects on the blue and red discrimination than for either the first five trials of the green and brown discrimination ($p.=.01$) or the first five trials of the ink drawing discrimination ($p.=.001$). 2) For the high school subjects, the pupil response was significantly lower for the blue and red discrimination

than the Chinese figure discrimination (p.=.05). 3) On the blue and red discrimination, the pupil response for the kindergarten subjects was significantly lower than the response of the high school subjects (p.=.001). The response on the last trial was significantly lower for the high school subjects when compared to the response on the first trial on both discriminations. (p.=.01 for the blue and red square; p.=.05 for the Chinese figures.) All comparisons were made with the Mann-Whitney U-test.

The differences given above would indicate that 1) Less cognitive activity is involved when the kindergarten subjects were tested on a learned discrimination as compared to cognitive activity while learning a discrimination. 2) For the high school subjects, less cognitive activity was involved in learning the discrimination with the squares than with the Chinese figure discrimination. 3) That the high school subjects expended less cognitive activity on trials at the end of training on a discrimination than on the initial trial, a relationship which did not hold true for the kindergarten subjects.

In addition, the kindergarten subjects showed considerably more trial-to-trial response variability in pupil changes while learning a new discrimination than was shown on the discrimination after learning (the blue and red discrimination) or than was shown by the high school subjects during discrimination learning.

Verbal and Pupil Data During Mental Problem Solving. The kindergarten subjects only had one series which fell into this category. They were asked to answer three questions while the pupil response was recorded: "What is your name?" "What is your teacher's name?" and "What is your best friend's name?" This particular series presented difficulty because there was more movement on the part of the subjects, probably because they were looking at a fixation point, rather than at visual material which would be more effective in holding their attention. As a consequence, approximately one-third of the film data was lost in each group.

The verbal responses and pupil changes while engaged in problem solving activity are shown in Tables 3, 4, and 5.

While with the kindergarten subjects there was a tendency for fewer of the disadvantaged children to respond to questions (Table 3), this difference was not significant, even in response to the question, "What is your teacher's name?", where 7/22 of the middle-class group failed to respond, compared to 12/22 of the disadvantaged non-Caucasian subjects (Chi-square Test). There were no significant differences in the pupil response, either between groups or between problems (Mann-Whitney U-test), although the middle-class subjects tended to have smaller responses.

Table 4 shows the verbal response for the high school subjects. There was little difference between groups or problems for the hidden figures or the multiplication problems. There was, however, a significant difference between the number of subjects answering the three anagram problems (Chi-square Test). The difference in the number of subjects responding to "olop"

and "rownb" was significant at the .01 level; in the number responding to "olop" and "ictano" significant at the .0001 level; and, the difference in the number responding to "rownb" and "ictano" was significant at the .001 level. These differences appear to reflect the difficulty of the problems. It might be noted that in the case of the anagrams and hidden figures, the subjects either responded correctly, or did not respond at all. This was not the case with the multiplication problems.

The difficulty of the anagram series was also reflect in the increases in pupil size while solving the problems. The mean increase in pupil size for the three words, for all subjects was 5.2% (olop), 6.4 (rownb) and 9.8% (ictano). The only significant difference for the pooled subjects was between "olop" and "ictano" ($p_{\circ}=.01$, Mann-Whitney U-Test).

While there was greater dilation while looking for the number 7 than for the hamburger, this difference was not significant.

For the series of multiplication problems, a significant difference was found in the pupil response to the three problems. The difference between the 7 x 12 and 8 x 16 was significant at the .02 level; between 7 x 12 and 13 x 17, $p_{\circ}=.001$; between 8 x 16 and 13 x 17, $p_{\circ}=.01$. (Mann-Whitney U-Test, all subjects.)

A significant difference was also found in pupil scores between groups when a comparison was made between the combined middle-class and combined disadvantaged populations (providing an N of 30 in each group). For the problem 7 x 12, $p = .05$ for 8 x 16, $p = .02$; and for 13 x 17, $p = .05$.

Verbal and Pupil Responses to Forms, Numbers, Colors and Objects. Tables 6 and 7 show the verbal and pupil responses for the kindergarten subjects to the series of forms, number, colors and objects. Analysis of the verbal data showed that: 1) For the forms, when subjects are pooled, identification of the triangle is significantly poorer than identification of both the circle and square (in both comparisons, $p_{\circ} = .0001$). Between group difference showed the KDNC group to be significantly poorer in the identification of all three forms than the KDC group ($p = .02$) and the KMC group ($p_{\circ} = .001$). The difference between groups KDC and KMC was not significant. (Chi-square-Test). 2) When the responses of all subjects are pooled, identification of the number 9 is significantly poorer than the identification of all other numbers (9 vs. 3, $p = .001$; 9 vs. 4, $p = .001$; 9 vs. 7, $p = .02$; 9 vs. 8, $p = .02$). Group comparisons showed the KDNC group to be significantly poorer than the two other groups in number identification. For the five numbers, group KMC had 84.5% correct identifications, group KDC 89.0% and group KDNC 69.0%. The difference between groups KDNC and KMC is significant at the .01 level and the difference between groups KDNC and KDC is significant at the .001 level. (Chi-Square-Test). 3) There were no differences between groups or stimuli for the three colors. 4) It is clear that identification of the Kennedy half-dollar was poor in all groups (for all Ss, identification of both other objects was significantly better at greater than the .001 level).

This was largely due to calling the half-dollar a nickle (32.8%) a dime (31.2%) or a penny (13.1%). Only 8.1% of the subjects failed to respond. While group KDNC was poor in the identification of the pliers, this difference was not significant when compared to the two other groups. There was, however, a significant difference in the ability of the middle-class children to identify the can opener (KMC vs. KDC, p = .03; KMC vs. KDNC, p = .05) (Chi-square-Test.)

The pupil data while viewing the forms, numbers, colors and objects is shown in Table 7. For all groups of subjects the response to the circle was greater than to the last square in the series. (KMC, p = .05; KDC, p = .02; KDNC, p = .01.) This same relationship was true for the response to the inverted triangle as compared to the last triangle in the series. (KMC, p = .02; KDC, p = .02; KDNC, p - .01) (Mann-Whitney U-Test) Differences between groups were not significant.

For the series of numbers, there were no significant differences in the response to the different numbers or in the responses of the different groups. There was, however a significant difference for each number between the initial pupil response and the response when the subject was asked to identify the number (in all cases p = .01, Mann-Whitney U-Test).

The same relationship was true with the blue and green stimuli, although the significance level was .05. (Mann-Whitney U-Test). The initial response to red for the combined subjects was significantly higher than the response to the two other colors (red vs. green, p = .05; red vs. blue, p = .02; Mann-Whitney U-Test). While there was not a significant difference in group responses to any single color, the response of group KDNC was significantly higher when their scores to all three colors on the first presentation where compared with the two other groups. (In both cases p = .05, Mann-Whitney U-Test).

The responses of the kindergarten subjects to the three objects showed several clear-cut relationships. First, the total response of the three groups of subjects is higher to the half-dollar on the first presentation than to the two other objects (half-dollar vs. pliers, p = .02; half dollar vs. can opener, p = .001). In regard to this same stimulus, the responses of the disadvantaged groups was higher than the response of the middle-class group (KMC vs. KDC, p = .02, KMC vs. KDNC, p = .01). In all cases, the response to the half-dollar was lower on the second presentation. The only significant differences between the two presentations of the objects was the pupil response to the pliers for group KDNC (p = .01) and the pupil response of group KMC to the can opener (p = .01). There was also a significant difference (on the second presentation only) in the response of group KDNC to the pliers and of group KMC to the can opener. For the pliers, the response of group KDNC was significantly different from group KDC at the .02 level and significantly different from the response of group KMC at the .05 level. The response of group KMC was significantly higher for the second presentation than both other groups at less than the .01 level. (Mann-Whitney U-Test.)

Table 8 shows both the verbal and pupil data for the high school subjects to the single series of objects shown these subjects. For the correct verbal identifications, there were no significant difference groups. However, identification of both the half-dollar and can opener was significantly better than identification of either the wire strippers or resister ($p = .001$, in all case, Chi-square Test).

The pupil responses to the second presentation of the wire strippers was significantly higher in all groups, as compared to the response on the first presentation (HMCI, $p = .02$; HMCII, $p = .01$; HDM, $p = .05$; HDN, $p = .02$). Both group HDM and HDN showed significantly higher responses to the resister on the second presentation ($p = .05$, for both groups). On the first presentation, when the responses of all subjects are pooled the response to the half-dollar is significantly higher than the response to the wire strippers ($p = .05$) and can opener ($p = .02$), and, the response to the resister is significantly higher than the response to the wire strippers ($p = .01$) and the can opener ($p = .001$). There are a few isolated differences between groups in the pupil data. Group HMCII had a significantly higher response to the wire strippers on the second presentation than group HDN ($p = .05$). The responses of both middle-class groups were also significantly lower on the second presentation of the resister, when compared to the disadvantaged groups. (HMCI vs. HDM, $p = .05$; HMCI vs. HDN, $p = .02$; HMCII vs. HDM, $p = .05$; HDMCII vs. HDN, $p = .01$). (Mann-Whitney U-Test.)

Verbal and Pupil Data to the Street-type figures. The fourth category of stimuli used in this study were the two sets of Street-type figures (one set was presented to the kindergarten subjects, both sets to the high school subjects). Table 9 shows the percent correct verbal identification of these figures for both the kindergarten and high school subjects. The pupil data is presented in Table 10.

Collectively, the kindergarten subjects had significantly lower verbal scores to the chair, than to the three other figures (chair vs. house, $p = .01$; chair vs. tree, $p = .01$; chair vs. TV., $p = .001$). The only significant group differences were between groups KDNC and KDC. The difference in the percent correct identifications of the chair was significant at the .05 level for these groups and the difference in correct identification for all four stimuli was significant at the .02 level (Chi-square Test).

For the high school subjects, there were no significant differences between groups. For Set I, there were significantly more errors in identifying the chair than in identifying the T.V. set, when the scores of all subjects are pooled ($p = .001$).

For Set II, there were, among all subjects, significantly fewer positive identifications of the coke bottle than the house ($p = .03$), the coke bottle than the sport car ($p = .05$), the stereo than the house ($p = .001$) and the stereo than the sport car ($p = .01$). (Chi-square Test).

The pupil data for the kindergarten children (Table 10) again shows

some isolated instances of differences between groups. The response of group KDC was significantly higher than the response of group KDNC to both the chair (p = .01) and the house (p = .05). Between stimuli, the only significant response differences were in group KDNC. The response to the chair was significantly lower than the response to the tree and the T.V. set (in both cases, p = .01) and the response to the house was significantly lower than the response to the tree and the T.V. set (p = .02 and .05, respectively). (Mann-Whitney U-Test.)

The pupil data for the high school subjects, also presented in Table 10, shows a few isolated differences between the responses of the four groups. For all stimuli in Set I, the response of group HMCI was significantly lower than the three other groups (in all cases, p = .05), group HMCII was significantly lower than group HDN in its response to the T.V. set (p = .05) and the response of group HDN was significantly lower for the tree when compared to group HDM (p = .05). (Mann-Whitney U-Test.)

For Set II, the combined responses of the four groups was significantly lower for the horse than for the three other stimuli (house vs. sport car, p = .001; house vs. coke bottle, p = .01; house vs. stereo, p = .01). There were no significant differences between groups on any of the stimuli.

Table 11 shows the mean percent correct verbal identifications and the mean changes in pupil size for the four groups of high school subjects to the two sets of Street-type figures. The combined total of eight stimuli make it possible to do a correlation between the two sets of scores. A negative correlation of .84 (Spearman Rank Correlation Coefficient) between identification of the figures and pupil size, when highest percent correct identification is given the rank of "1" and the largest change in pupil size while viewing the stimulus is given a rank of "1". This correlation is significant at the .01 level.

Summary of Significant Findings - Verbal Responses. The verbal responses of the kindergarten subjects showed poor identification of a triangle, relative to a circle and a square; poor identification of the number 9, relative to the numbers 3, 4, 7 and 8; poor identification of a Kennedy half-dollar, relative to a pair of pliers and a can opener; poor identification of a chair, relative to a house, tree and television set, in a set of pictures lacking closure. These findings would appear to reflect an inability to accurately label a number of objects commonly encountered in the environment. In addition, differences in the ability to correctly identify objects were noted between groups. The disadvantaged non-Caucasian subjects had significantly lower responses to the forms and numbers than both aucasian groups, and significantly fewer correct identifications of the can opener than either disadvantaged group. (Which may be an interesting reflection on cultural differences between groups.)

All signigicant differences in the high school subjects were between stimuli, apparently a direct function of item difficulty. These differences

were seen in the three anagram problems, the lack of familiarity with the wire strippers and resister, as compared to the can opener and half-dollar and the difficulty in identifying the chair, coke bottle and stereo among the figures lacking closure.

Summary of Significant Findings - Pupil Responses. There were a number of significant differences in the pupil responses of the kindergarten subjects, both between stimulus items and between groups.

The following differences were found between the various stimuli in the kindergarten subjects:

1) Responses were greater while learning the discrimination of green and brown squares and the discrimination involving the ink drawings than when subjects were tested on a discrimination on which they had been given previous training (the large and small red and blue squares). Responses were also significantly large for the ink drawing discrimination than for the green and brown squares.

2) Responses were larger to a novel stimulus, presented after four repetitions of the same stimulus, than to the fourth presentation of the original stimulus.

3) Responses were significantly higher when subjects were asked to identify the number 3, 4, 7, 8, and 9, and the colors blue and green as compared to simply looking at the numbers and colors on their initial presentation. This was also true of the response to the pliers and can opener.

4) The response to the color red was significantly higher on the inital presentation than the response to the colors blue and green.

5) The initial response to the half-dollar was significantly higher than the response to the pliers and can opener.

The following significant differences were found between the responses of the three kindergarten groups:

1) For the initial presentation, the response to the color red was higher for the non-Caucasian subjects than the response to this color in either Caucasian group.

2) The response to the half-dollar was higher in both disadvantaged groups, when compared to the response of the middle-class subjects.

3) The disadvantaged non-Caucasian subjects had a higher response to the pliers, when asked to identify the object than when simply looking at the object. This was also the case with the middle-class subjects for the can opener.

4) The response to the Street-type figures of the chair and the house was higher for the disadvantaged Caucasian subjects than for the disadvantaged non-Caucasian subjects.

5) The disadvantaged non-Caucasian subjects were the only ones which showed response differences to the Street-type figures. The response was significantly higher to the tree and the T.V. set than to the chair and the house.

In the high school subjects, there were a number of significant differences between stimuli, and a few differences in group responses. Differences between the various stimuli and tasks included:

1) Larger changes in pupil size while solving the Chinese figure discrimination, as compared to the discrimination with the large and small blue and red squares.

2) Larger responses while trying to make a word out of the letters I, C, T, A, N, O as compared to constructing a word out of the letters O, L, O, P.

3) Differences in pupil size while 7 x 12 and 8 x 16, 7 x 12 and 13 x 17, and 8 x 16 and 13 x 17.

4) Each of the four groups showed a significantly higher response when asked to identify the wire strippers on the second presentation of this stimulus, than their response on the first presentation of the stimulus. On the initial presentation of this series of stimuli, the pooled response of all subjects were higher to the half-dollar, than to wire strippers and can opener, and higher to the resister, than to the wire strippers and can opener.

5) For the Street-type figures, the pupil response to the horse was significantly lower than to the three other stimuli in the series, the sports car, the coke bottle and the stereo.

Differences between high school groups on the pupil response to the various stimuli used in this study were:

1) When a comparison was made between all middle-class subjects and all disadvantaged subjects, responses were significantly higher when solving all three problems in the disadvantaged subjects.

2) There were significant differences in the response to the resister on the first and second presentations of the stimulus only in the two disadvantaged groups. (The response was higher on the second presentation, in both cases.)

3) On the second presentation only, group HMC II had a higher response to the wire strippers than group HDN: both groups HMC I and HMC II had lower responses to the resister than groups HDM and HDN.

4) When shown Set I of the Street-type figures, group HMC I had a lower pupil response when compared to each of the three other groups; group HDN had a higher response to the T.V. set than group HML II; group HDM had a higher response to the three than group HDN.

5) When the mean of all 60 high school subjects was tabulated for identification of the eight Street-type figures and the pupil response to these figures, an inverse relationship was found between correct identifications and magnitude of pupil change to the stimuli. High identification scores were related to low pupil response and low identification scores were related to high pupil responses. This relationship was significant at the .01 level for the eight stimuli.

Table 1. Mean percent change in pupil size for three groups of kindergarten subjects while solving and responding to three discrimination problems.

Discrimination and Group	Trials							
	1	2	3	4	5	6	7	8
Green and Brown Squares								
KMC	6.7	7.3	5.8	6.5	8.2	5.5	6.3	4.8
KDC	5.9	5.0	6.6	6.2	4.8	5.9	4.6	5.4
KDNC	6.1	8.3	5.9	5.6	7.1	5.1	4.9	4.7
Ink Drawings								
KMC	9.6	10.3	12.1	9.7	9.3	10.6	9.2	10.4
KDC	8.6	8.8	10.7	8.0	9.1	7.6	7.2	7.9
KDNC	10.6	9.4	11.3	9.5	8.6	8.2	9.0	8.1
Blue and Red Squares								
KMC	3.7	3.5	4.1	3.4	2.2	-	-	-
KDC	2.6	3.2	2.4	2.9	2.1	-	-	-
KDNC	3.2	4.0	4.0	2.7	3.6	-	-	-

Table 2. Mean percent change in pupil size for four groups of high school subjects while solving two discrimination problems.

Discrimination and group	Trials 1	2	3	4	5	6	7	8
Blue and Red Squares								
HMCI	8.3	6.5	5.2	4.6	4.4	-	-	-
HMCII	7.8	7.2	6.3	5.8	5.3	-	-	-
HDM	11.3	8.6	8.7	7.0	6.1	-	-	-
HDN	10.3	10.5	9.1	7.8	5.9	-	-	-
Chinese Figures								
HMCI	9.8	11.2	11.7	10.8	9.4	9.4	8.7	8.1
HMCII	10.6	10.8	9.8	9.5	9.2	8.3	8.0	8.3
HDM	9.6	10.8	11.1	9.4	9.7	9.9	8.6	9.1
HDN	11.3	12.1	10.8	10.6	8.4	8.7	9.0	7.7

Table 3. Verbal and pupil responses for three groups of kindergarten subjects to three questions. The verbal response to the third question could not be classified as correct or incorrect. The verbal response is given in terms of the percentage of subjects answering correctly. The number of subjects in each group which did not respond is given in parenthesis. The pupil response is the mean of the five consecutive frames at the peak over the control level.

	What is your name?	What is your teacher's name?	What is your best friend's name?
Verbal Response			
KMC	100 (6)	88 (7)	N/A (7)
KDC	100 (8)	70 (10)	N/A (9)
KDNC	100 (8)	60 (12)	N/A (11)
Pupil Response			
KMC	+6.8	+11.4	+10.7
KDC	+9.2	+13.6	+11.8
KDNC	+9.7	+12.8	+13.4

Table 4. Verbal responses of four groups of high school subjects to three sets of problems which were solved mentally. Scores given are the mean percent correct responses, with the number of subjects that did not respond given in parenthesis. On the second and third sets of problems, S either gave the correct response, or did not respond at all, therefore, there were no response errors.

Multiplication Problems	7 x 12	8 x 16	13 x 17
HMCI	84.75 (2)	78.00 (2)	73.00 (4)
HMCII	92.00 (3)	84.75 (2)	66.50 (3)
HDM	92.00 (3)	82.00 (4)	82.00 (4)
HDN	93.00 (1)	84.75 (2)	80.00 (5)

Anagrams	OLOP (LOOP, POOL, POLO)	ROWNB (BROWN)	ICTANO (ACTION)
HMCI	100.00 (3)	100.00 (6)	100.00 (12)
HMCII	100.00 (2)	100.00 (8)	100.00 (13)
HDM	100.00 (4)	100.00 (4)	100.00 (11)
HDN	100.00 (2)	100.00 (6)	100.00 (12)

Hidden Figures	Hamburger	Number 7
HMCI	100.00 (0)	100.00 (2)
HMCII	100.00 (1)	100.00 (3)
HDM	100.00 (0)	100.00 (3)
HDN	100.00 (2)	100.00 (4)

Table 5. Mean percent increase in pupil size of four groups of high school subjects to three sets of problems which were solved mentally. These scores reflect the difference in pupil size between the control period, immediately before the problem was presented and the mean pupil size during the five second period at the peak during problem solving.

Multiplication Problems	7 x 12	8 x 16	13 x 17
HMCI	5.8	7.4	10.9
HMCII	4.9	7.0	11.2
HDM	6.9	10.8	13.3
HDN	6.7	9.4	14.8
Anagrams	**OLOP**	**ROWNB**	**ICTANO**
HMCI	4.7	6.7	9.9
HMCII	4.2	5.5	10.3
HDM	6.0	6.3	10.6
HDN	5.8	7.1	8.4
Hidden Figures	**Hamburger**	**Number 7**	
HMCI	2.7	5.7	
HMCII	3.4	4.3	
HDM	3.0	6.4	
HDN	4.2	5.6	

Table 6. Percent correct verbal identification of geometric forms, numbers, colors and objects by three groups of kindergarten subjects. Failure to respond was counted as an incorrect response.

Geometric Forms	Triangle	Circle	Square
KMC	63.6	91.0	81.8
KDC	40.0	90.0	85.0
KDNC	22.8	59.0	68.1

Numbers	3	4	7	8	9
KMC	91.0	95.5	91,0	77.2	68.1
KDC	95.0	100.0	90.0	90.0	90.0
KDNC	81.8	72.7	68.1	77.2	45.5

Colors	Green	Blue	Red (pink, orange)
KMC	81.8	91.0	91.0
KDC	85.0	90.0	85.0
KDNC	77.2	91.0	100.0

Objects	Pliers	Can Opener	Half-dollar
KMC	59.0	18.2	18.2
KDC	55.0	55.0	15.0
KDNC	36.7	52.8	10.5

Table 7. Mean percent increases in pupil size of three groups of kindergarten subjects while viewing geometric forms, numbers, colors and objects. Scores given in parenthesis for the numbers, colors and the objects indicate the pupil response on the second presentation of the stimulus, when subjects were asked to verbally identify the stimulus.

Geometric Forms	Square 1	Square 2	Square 3	Square 4	Circle
KMC	3.6	4.8	4.9	3.9	5.7
KDC	3.8	3.5	4.7	4.4	6.2
KDNC	4.4	3.9	4.6	4.2	6.9

	Circle 1	Circle 2	Circle 3	Circle 4	Square
KMC	5.2	4.9	4.6	4.0	6.3
KDC	4.7	6.1	5.3	5.6	7.4
KDNC	5.6	4.9	4.4	3.9	6.8

Numbers	3	4	7	8	9
KMC	2.1(5.2)	2.4(4.8)	3.6(5.9)	2.7(3.6)	4.1(8.6)
KDC	3.0(6.1)	2.8(5.5)	3.3(5.0)	3.6(5.2)	5.1(7.7)
KDNC	3.6(6.8)	3.1(5.9)	4.2(7.3)	2.8(6.4)	3.9(6.4)

Colors	Green	Blue	Red (pink, orange)
KMC	3.7(4.6)	3.4(4.9)	5.4(5.7
KDC	3.5(5.2)	2.8(4.9)	4.9(6.0)
KDNC	4.6(6.2)	5.1(6.6)	6.5(6.3)

Objects	Pliers	Can opener	Half-dollar
KMC	7.0(8.1)	6.4(9.7)	8.8(6.1)
KDC	6.3(7.3)	5.3(6.2)	11.2(9.0)
KDNC	7.4(9.9)	5.6(6.7)	12.5(10.3)

Table 8. Mean percent correct verbal identification of four stimulus objects by four groups of high school subjects and mean percent increase in pupil size while viewing these objects. The pupil score in parenthesis indicates the response on the second presentation of the object, when subjects were asked to identify the object.

Percent Correct Verbal Responses	wire strippers	can opener	half-dollar	resister
HMCI	33.30	93.40	100.00	20.00
HMCII	40.00	100.00	100.00	33.30
HDM	52.80	100.00	100.00	40.00
HDN	46.60	100.00	100.00	33.30

Percent Change in Pupil Size	wire strippers	can opener	half-dollar	resister
HMCI	4.7(7.3)	3.9(3.1)	5.8(4.2)	6.1(6.9)
HMCII	3.9(8.6)	3.3(4.2)	4.7(4.6)	5.8(5.9)
HDM	5.1(7.1)	4.0(2.8)	6.2(5.4)	6.9(8.3)
HDN	4.8(6.7)	4.6(3.7)	5.4(4.0)	7.3(92.)

Table 9. Mean percent correct verbal identification of two sets of Street-type figures by three groups of kindergarten subjects and by four groups of high school subjects.

Street figures, Set I, Kindergarten subjects	Chair	House	Tree	T.V. set
KMC	45.5	77.2	68.1	95.5
KDC	63.3	79.0	68.5	94.8
KDNC	22.2	50.0	72.3	94.5

Street figures, Set I, High school subjects	Chair	House	Tree	T.V. set
HMCI	80.0	86.7	80.0	100.0
HMCII	73.4	80.0	86.7	100.0
HDM	80.0	86.7	73.4	100.0
HDN	66.6	80.0	73.4	100.0

Street figures, Set II, High school subjects	Horse	Sport Car	Coke Bottle	Stereo
HMCI	86.7	80.0	53.4	40.0
HMCII	80.0	73.4	40.0	33.3
HDM	80.0	66.6	53.4	53.4
HDN	73.4	66.6	60.0	46.6

Table 10. Mean percent increases in pupil size to two sets of Street-type figures by three groups of kindergarten subjects and by four groups of high school subjects.

Street figures, Set I, Kindergarten subjects	Chair	House	Tree	T.V. set
KMC	5.9	6.8	7.3	6.2
KDC	6.8	7.2	6.4	7.9
KDNC	4.0	5.4	7.9	7.1

Street figures, Set I, High school subjects	Chair	House	Tree	T.V. set
HMCI	5.4	6.1	6.8	5.0
HMCII	7.0	4.9	6.3	4.1
HDM	7.3	5.1	7.1	5.6
HDN	7.8	6.3	4.6	6.1

Street figures, Set II, High school subjects	Horse	Sport Car	Coke Bottle	Stereo
HMCI	4.6	8.7	8.3	7.4
HMCII	4.2	9.9	8.4	7.9
HDM	4.7	9.2	9.4	8.3
HDN	6.1	8.6	8.6	9.3

Table 11. Mean correct verbal identifications and mean pupil responses of four groups of high school subjects (N=60) to two sets of Street-type figures. In ranking, the highest percent correct identifications and the highest pupil response are given the rank of "1". The correlation between scores is -.84 (Spearman Rank Correlation Coefficient).

	Mean Percent Correct Identification	Rank	Mean Pupil Response	Rank
Set I.				
Chair	75.0	5	6.9	4
House	81.7	2	5.6	6
Tree	78.4	4	6.2	5
T.V. set	100.0	1	5.2	7
Set II.				
Horse	80.0	3	4.9	8
Sport Car	71.6	6	9.1	1
Coke Bottle	51.7	7	8.7	2
Stereo	43.3	8	8.0	3

DISCUSSION

The discussion of the experimental findings will be divided into three parts, relative to the first, second and fourth research objectives as presented in the initial research proposal and the introduction of this report, followed by a discussion of this research in relation to other research in this area, an evaluation and conclusions.

Comparison of the Pupillary Response as a Measure of Cognitive Functioning in Middle-Class and Disadvantaged Populations. While a few significant differences were found among both the kindergarten and high school subjects, in consideration of the number of tasks and stimuli involved, there is no conclusive evidence that the disadvantaged and middle-class subjects constitute two clearly distinct populations in the areas encompassed by this study, when pupillary activity is used as a measure of cognite functioning.

The pupil data appears to be a valid measure of cognitive functioning in both the kindergarten and high school subjects. In some cases, increased pupil size reflected problem difficulty and correlated with the subjects' verbal response. In other cases differences in pupil response occurred which were not evident in the subjects' verbal behavior.

For the kindergarten subjects differential cognitive activity was seen in the difference in pupil size while learning discrimination problems as compared to the pupil size while being tested on a previously learned problem. This result would indicate that the mental activity decreases as performance continues after the stage of initial learning. This interpretation is further supported by the finding that pupil dilation was less while learning a relatively simple discrimination (green vs. brown squares) as compared to a more difficult discrimination (the ink drawings).

It was also found that the size of the pupil was significantly larger when subjects were required to verbally identify stimuli than when there was passive viewing of the stimuli. This was true of the five numbers, two of the three colors and two of the three stimuli in the series of objects. The two stimuli which did not show this effect were the color red and the half-dollar. In both cases, the initial response to these stimuli was higher than to the other stimuli in their respective series. The higher initial response to these stimuli (which minimized the probability of obtaining significant increases during the second presentation, when subjects were asked to identify the stimuli) is consistent with the general finding that the pupil response reflects both emotional impact of stimuli and the interest value of the stimulus.

Unpublished research (14) has indicated that under conditions of controlled brightness, colors presented to subjects elicit differential responses, and that red is among those colors which draws a strong reaction. It is also not surprising that the half-dollar was of high interest value

to the subjects. The finding that the response of the disadvantaged groups was significantly higher than the middle-class group would be in line with one of the classical studies in perception, where it was found that children from lower socioeconomic groups judged coins as being larger in size than subjects from higher socioeconomic groups (15).

Those stimuli which were not contaminated by the extraneous factors mentioned above (the numbers 3, 4, 7, 8, and 9; the colors blue and green; the pliers and the can opener) which elicited a larger pupil response when a verbal identification was requested from the child, substantiate the result with the discrimination problems: increased pupil size is a direct function of increased cognitive activity. This seems to support the feasibility of using this technique as a measure of cognitive functioning.

The differences between the groups of kindergarten subjects were isolated and appear to be related more to interest aroused by the stimuli than in differences in intellectual capacities. Two of these differences have already been mentioned; the higher response of the disadvantaged subjects to the color red and to the half-dollar. There were several differences to the Street-type figures which appear to be related to interest: these were the higher responses of the disadvantaged non-Caucasian subjects to the tree and the T.V. set in comparison to the chair and the house.

The other significant differences between groups was the higher response of the group KDNC to the pliers on the second presentation and of group KMC to the second presentation of the can opener. These were both stimuli which had been low in verbal identification in the respective groups. Here again there is evidence that increased pupillary activity is related to the cognitive effort required by the task. The interpretation assumes that more mental effort is required when the S does not know the answer to the problem than when the answer is readily available.

As with the kindergarten subjects, the pupil data for the high school subjects indicates differences in cognitive activity between tasks, with higher pupil responses associated with those stimulus situations requiring more mental activity. This was true of the two discrimination problems, the anagrams and the multiplication problems. Higher pupil responses were also found on the second presentation of the wire strippers, when subjects were asked to identify this stimulus, as compared to the initial response to the wire strippers.

In regard to group differences, those which seem meaningful were the findings that the disadvantaged groups showed a higher response while solving the multiplication problems and in their second response to the wire strippers and resister. In both cases it appears that cognitive activity was higher in the disadvantaged subjects while solving the problems and while identifying the wire strippers and resister. Since these differences were not seen in the verbal responses, pupillary activity appears to be a more sensitive measure of cognitive functioning in these situations than response errors.

Some of the isolated differences between groups presented in the results section, such as the lower response of group HMCI to the first set of Street figures, show little consistency and may actually be chance differences.

It is also evident in examining the group data, that there is little difference between the two groups of middle-class subjects. This would point to consistency between similar groups, even with an N as small as 15. However, it should also be kept in mind that the major significance differences between the disadvantaged and middle-class populations were found where the data from the two groups was pooled, providing an N of 30.

In summary it is concluded that: a) Pupillary activity is a valid measure of cognitive functioning in the populations encompassed by this research; and, b) That no substantial differences exist in cognitive functioning, as measured by pupillary activity, in either population.

Pupillary vs. Verbal Measures of Cognitive Ability. Differences in verbal responses, in terms of errors and inability to solve problems and identify stimulus objects, were found both between stimuli and between groups. In the kindergarten subjects this is seen in the response to the triangle (relative to other forms), the number "9" (relative to other numbers), the half-dollar (relative to a pair of pliers and a can opener) and the chair (relative to other Street-type figures). These differences may reflect poor labeling ability, which seems to extend across subjects. This is most clearly the case with the half-dollar. The children labeled it a coin, but were inaccurate in the denomination.

In considering identification of all forms and all numbers, the disadvantaged non-Caucasian subjects had lower scores than both Caucasian groups. This difference may have been due to less experience with these stimuli on the part of the disadvantaged populations. Items such as this are also frequently found on standard intelligence tests which have shown differences between disadvantaged and middle-class children at this age level.

The verbal responses of the high school subjects showed no differences between groups, although there were differences in the problems and stimuli within series. Correct responses to the three sets of letters in the anagram series were directly a function of problem difficulty. The poor scores on the identification of the wire strippers and resister can be attributed to the novelty of these stimuli to the average person. (Which, in fact, is why they were selected as stimuli.) Fewer correct identifications of the chair, coke bottle and stereo also reflect the greater complexity of these stimuli relative to others in the series.

All differences in the verbal responses of the high school subjects seem to be purely a reflection difficulty or lack of familiarity with stimulus objects. It would be surprising if differences did not occur in

the ability to form a word from the two combinations of letters "olop" and "ictano", or in the ability to identify a common object such as a half-dollar and a rather specialized object, such as a resister.

The high school pupil data substantiated the kindergarten data in relation to increased pupillary activity associated with situations requiring greater mental activity. This is perhaps one of the most important findings in this study, that at both the kindergarten and high school levels the pupil response is sensitive to differential cognitive functioning, which in some cases was not evidenced in verbal scores.

Another important result in the high school data was the correlation between the verbal identification of the eight Street-type figures and the pupil response to these figures. This would suggest that there may be other situations, where the pupil response would detect differences in cognitive functioning which are not evidenced in verbal responses.

Comparison Between Middle-Class and Disadvantaged Subjects at the Kindergarten and High School Levels. As indicated in the last two sections response differences obtained between middle-class and disadvantaged groups were more pronounced at the kindergarten level in the verbal data than in the data provided by the pupil response. On a very tentative basis, this would suggest that differences found between such populations (which will be discussed in greater detail in the section which follows) are more dependent on acquired verbal capacities than inherent cognitive ability. Of course, as an alternative it might be that pupillary activity is not as sensitive a measure of cognitive functioning as verbal responses. This is a question which might be answered through longitudinal studies, extending over several years with the same subjects. This would make possible determining characteristic response patterns for the individual subjects, from which deviant responses could be plotted.

For the high school subjects, there was less difference in the verbal responses between populations, and very few differences in pupil activity, A possible explanation for this finding, to be discussed in more detail in the next section, is that through a simple academic selection process, those disadvantaged high school students oriented toward college are intellectually homogeneous with the middle-class groups.

Relationship of the present research to other studies with disadvantaged populations. It is not within the scope of this study to comprehensively review that massive amount of data which has been collected comparing the performance of children and adolescents at different socioeconomic levels on a variety of tasks designed to measure cognitive development, academic ability and academic achievement. However, there are several factors which emerge from these studies which seem relevant to the present investigation.

1) The bulk of the work which has been done in this area has been done with younger children, typically from 5 to 10 years of age, and with a few exceptions, significant differences were noted in the performance of subjects

from high socioeconomic levels (middle and upper middle class background) and subjects from lower socioeconomic levels (the disadvantaged child). Among the exceptions are studies dealing with performance on nonverbal tasks (16, 17, 18). The most recent of these studies (18) reported little differences between middle-class white children on the Lowenfeld Mosaic Test, the Copy Form Test ("General behavior trends are highly similar.") and the Incomplete Man Test ("Striking similarity of the responses of the two groups."). Differences were found on I.Q. tests at all age levels (K through 5th grade) and on the Rorschach responses of older children.

2) Evidence seems to support the idea that the intellectual gap broadens between higher and lower socioeconomic groups as a function of time in the educational system. This was true of the Ames and Ilg study, cited above (18), where the percent of disadvantaged children showing academic promise generally declined from the first through fifth grades. This is also one theme of Pettigrew's book, A profile of the Negro American (19) who found that the longer the lower-class Negro child stayed in school, the further his performance deviated from the norms for his age and grade. Similar findings were reported 25 years ago by Warner (20) and more recently by Sexton (21), who both attribute this phenomenon to preferential treatment given the white middle-class student and lack of concern for the lower-class minority student.

Warner (20) concluded, in reference to differential academic treatment given children from high and low socioeconomic levels that, "Our educational system performs the dual task of aiding social mobility and, at the same time, working effectively to hinder it." And Sexton (21) found that since the curriculum of the elementary school reflects middle-class values, services are expended on those that need them least.

A notable exception to this trend is reported by Baughmand and Dahlstrom (22) who found differences in both academic ability and achievement between Negro and white students, but which remained relatively stable in groups ranging from five to ten years in age. They noted this deviation from the majority of findings, and could only suggest that differences might have been accentuated with increasing age, if longitudinal studies had been carried out with the same subjects.

3) A third recurring idea in the child developmental area as related to disadvantaged populations is the idea that deficiencies occuring in the educational context between disadvantaged and middle-class children are a direct reflection of differences in language skills. Bereiter and Englemann (23) represent this position, and, in effect, equate cultural deprivation with language deprivation. The lower-class child who must compete with the middle and upper-class child in a language system with which he is neither sufficiently skilled nor trained, begins his education at a distinct disadvantage.

This position is supported by Ryckman (24), who ran middle and lower-class Negro boys on a battery of 18 tests and found that the biggest difference between groups was in general language ability, followed by their

ability to label visual input. A similar conclusion was reached by Baughman and Dahlstrom (22) and by Chandler (25), who attributed poor reading ability in first graders from low socioeconomic backgrounds to lack of training in language and communication skills.

4) The last point that will be taken up here is the general conclusion that differences between high and low socioeconomic groups in the educational context is primarily due to basic differences in intelligence, with the implicit assumption that the deficiency found in the child from the low socioeconomic background can be negated through the use of appropriate training procedures. This is the contention of Chandler (25), Hess and Shipman (26), Odom (26) and Covington (28), among others.

The possible validity of this hypothesis is best demonstrated by the Covington study (28). Using the Discrimination Sub-test of the Primary Mental Abilities Test, Covington found, as had other studies, that the performance of middle-class kindergarten subjects was significantly superior to the performance of lower-class subjects. Since this test involves matching a "stem" object with three test objects (there are a total of 30 such sets), it was Covington's hypothesis that if the superiority of the middle-class child was due to familiarity with these or similar objects, training with the stem objects should be especially beneficial to the lower class child, and should be reflected in improved retest scores.

Initially, scores were significantly lower for the lower class experimental and control groups than for the respective middle-class groups. The experimental groups were then given intensive experience with pictures of the 30 stem objects, while the control groups had equal experience with pictures of animals. On retesting, the only group which showed a significant increase in correct responses was the lower-class experimental group, whose scores compared favorably with both middle-class groups. This result supported Covington's basic hypothesis: that poor performance on this test by children from low socioeconomic backgrounds is primarily due to lack of familiarity with test items.

To briefly summarize these points, it seems clear that: a) when compared to the performance of children from higher socioeconomic backgrounds, disadvantaged children do poorly on test of academic ability and of academic achievement; b) that this performance differential is greater on verbal than on nonverbal tests; c) that differences between the high and low socioeconomic groups increase with age from the fifth year on; d) that the poor performance of the lower-class child is largely due to poor language skills; e) that it is possible to compensate for the poor verbal performance of the disadvantaged child with appropriate training.

In one way or another, these points are relevant to the present study, or to possible applications of the present technique to future studies in this area.

In regard to point "a" above, while differences did occur in verbal responses between the middle-class and disadvantaged subjects, in terms of labeling geometric forms and numbers, these group differences did not occur with the pupil response. This is consistent with point "a" and also suggests that the pupil response may be a nonverbal measure of mental activity, where it has been found that lesser differences occur between socioeconomic levels than when verbal measures are used (point "b").

The data of the high school subjects showed virtually no group differences in verbal responses. Superficially, this would seem to contradict point "c", which was based on evidence that the differences in test scores, related to academic ability and achievement, increase between lower and middle-class students with increasing age. This discrepancy is probably due to one of the criteria used in the selection of the disadvantaged high school subjects; that the student be oriented toward a college education. Those disadvantaged students which might be clearly differentiated from the middle-class students may well have been eliminated from the subject pool, or, even more likely, have completely dropped out of school by the end of the junior year.

The pupil response scores did indicate group differences between the middle-class disadvantaged subjects while mentally solving problems. From the other pupil data, there seems to be little doubt that the disadvantaged subjects were expending more mental energy while solving the problems. However, this finding could be interpreted in several ways. It might indicate that more mental effort was required by the disadvantaged subjects to solve the problem, or, it might mean that more mental effort was expended in problem solving because the disadvantaged subjects were more strongly motivated to solve the problems. This question cannot be resolved from the present data, but it does eliminate a blanket conclusion that the disadvantaged subjects expended more mental effort in solving the problems <u>because</u> more effort was needed to solve the problems. The relationship of point "d" to the present data overlaps with point "b". That is, where differences between socioeconomic groups to occur, they are more likely to be related to verbal rather than nonverbal tasks.

The last point mentioned above, "e", will be taken-up in the next section as it relates to future pupillometric research suggested by the present study.

<u>Over-all Evaluation and Conclusions</u>. The strongest finding in this study is that pupillary dilation is directly related to cognitive activity in a number of situations requiring mental effort on the part of the subject, at the high school and kindergarten levels. In the kindergarten subjects, this was seen in the pupil response on discrimination problems and when asked to identify numbers, colors and objects. In the high school subjects, this was seen in a larger pupil response to more difficult problems, such as mental multiplication discrimination and forming words from scrambled letters. The pupil response was also significantly higher when the subjects were required to identify the wire strippers.

These findings are consistent with previous research in the area of pupillometrics (3,4,5), which showed pupillary dilation to be a direct function of mental activity. In most cases, the pupil data revealed response differences which were not evidenced in the verbal data, though it was found that in the verbal and pupil data of the high school subjects a significant inverse relationship existed between the pupil response to, and verbal identification of, the Street-type figures.

This suggests the feasibility of using the pupil technique in assessing cognitive activity in a variety of stimulus situations which might have implications for the educator. For example, it might be used as a diagnostic tool to determine if a child is really trying to achieve in an academic situation or whether poor performance is due to lack of effort (and perhaps motivation) as applied to academic achievement.

In regard to group differences in cognitive functioning, the present data strongly suggests that they are negligible in the populations covered in this study. If substantiated by further research, this could have important implications in structuring academic programs to benefit the disadvantaged child. But, as stated earlier (and this perhaps one weakness in the experimental design, at least in retrospect), the kindergarten and type of high school population used in this study are populations in which differences would be <u>least</u> likely to occur.

Largely due to the similarity in response between the two groups of middle-class high school subjects, which has only been briefly mentioned up to this point, the present study suggests sufficient stability in pupil scores to make possible the use of relatively small groups of subjects in studies of this type. There was one instance of a significant difference between the two middle-class high school groups, which, considering the number comparisons between groups might have been what has been traditionally called a Type I error in statistics: a statistically significant difference which is actually <u>not</u> significantly different.

One aspect of the research which was not completed as originally proposed dealt with follow-up correlations between the pupil data for each subject and future academic performance. Again, as a possible flaw in the experimental design, after the pupil data has been collected and tabulated there was no single piece of pupil data which seemed, on an <u>a priori</u> basis, a representative measure of the subjects cognitive ability. This was due to a lack of consistency across the various tasks in the pupil scores of individual subject. Totals of all scores produced fairly homogeneous scores across groups. In part, this may have been due to the wide variety of tasks on which the subjects were tested.

This study suggests several possible directions which future research might take to clarify the role cognitive functioning in the disadvantaged child. One possibility would be to carry-out research similar to the present research with subjects of intermediate age, utilizing data from the present study in the selection of stimuli.

As mentioned earlier, one hypothesis which has emerged from studies with higher and lower socioeconomic groups at the grade level is that the gap between populations broadens the longer the children are in school. Comparisons of groups of middle-class and disadvantaged children at the first, third, and fifth grade levels, on both verbal and pupil data, might indicate whether the amount of cognitive activity involved in these tasks deviates between groups with increasing age, as it would be anticipated that verbal scores would show progressively greater deviations.

Data from a study of this type might indicate a decline or lack of decline in cognitive functioning with increasing age in the disadvantaged child. If differences exist between populations at the verbal but not at what we might loosely call the cognitive level (i.e., the pupil response), it would suggest the existence of a latent cognitive capacity in the disadvantaged child which might be tapped through appropriate techniques. If differences exist between populations at both the verbal and cognitive levels, it would be of value to know the extent of deviations at the cognitive levels, and at what point they develop.

In the event of the latter result, we come back to the last finding mentioned in the previous section related to previous studies with lower socioeconomic populations. Point "e", that verbal differences between middle and lower-class students can be appreciably reduced through additional training of the lower-class students. It might be of value to know whether training procedures which raise performance at the verbal level would also effect cognitive activity as measured by the pupil response. If it did not, it is possible that the training has only a superficial, and probably a non-generalized, effect on the student's behavior. Along the same lines, it might be possible to try various training techniques, to find those which raise both the verbal and cognitive level of the child from a lower socioeconomic background.

This type of information might be of significant value to the educator concerned with developing the potential of the disadvantaged child, since it might provide information about the extent of cognitive functioning and those experiences which stimulate cognite activity and produce lasting changes in cognitive functioning.

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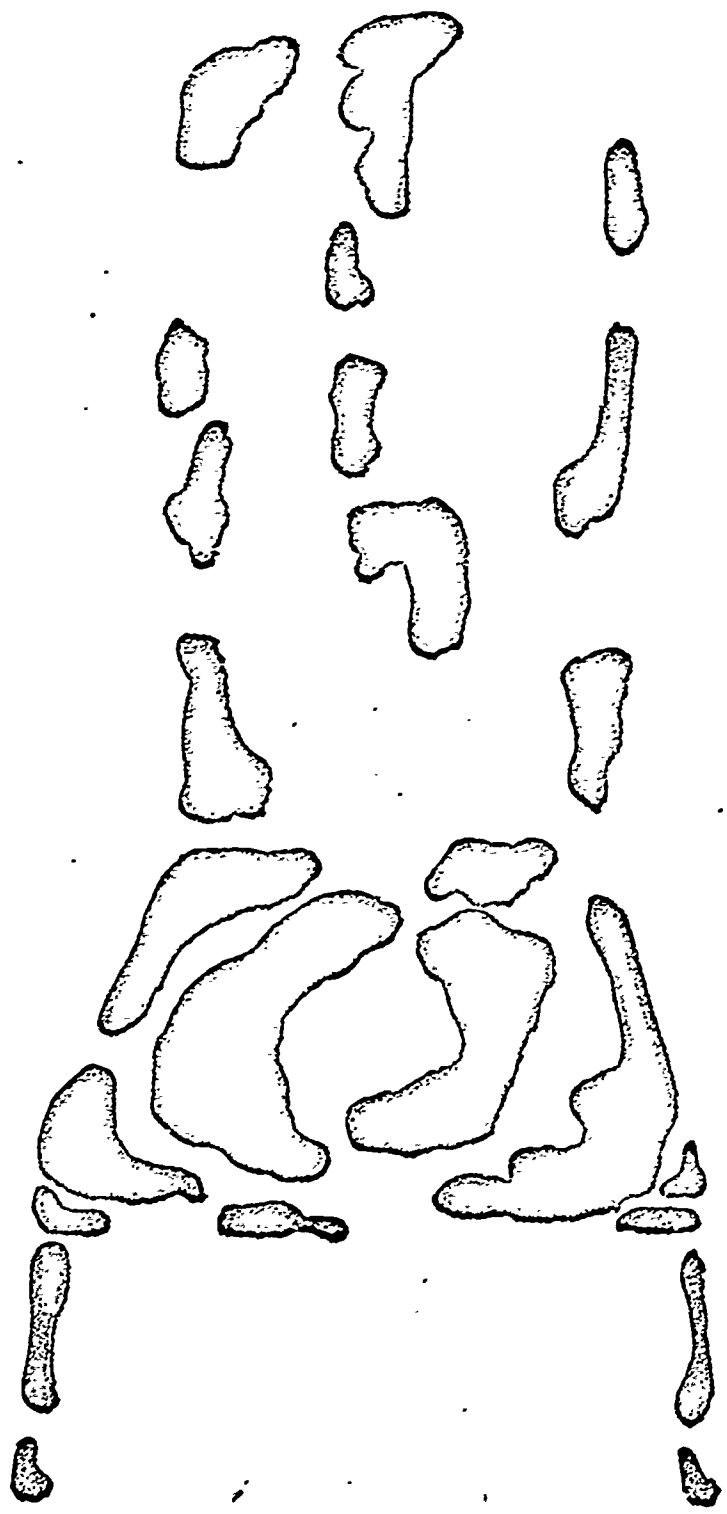
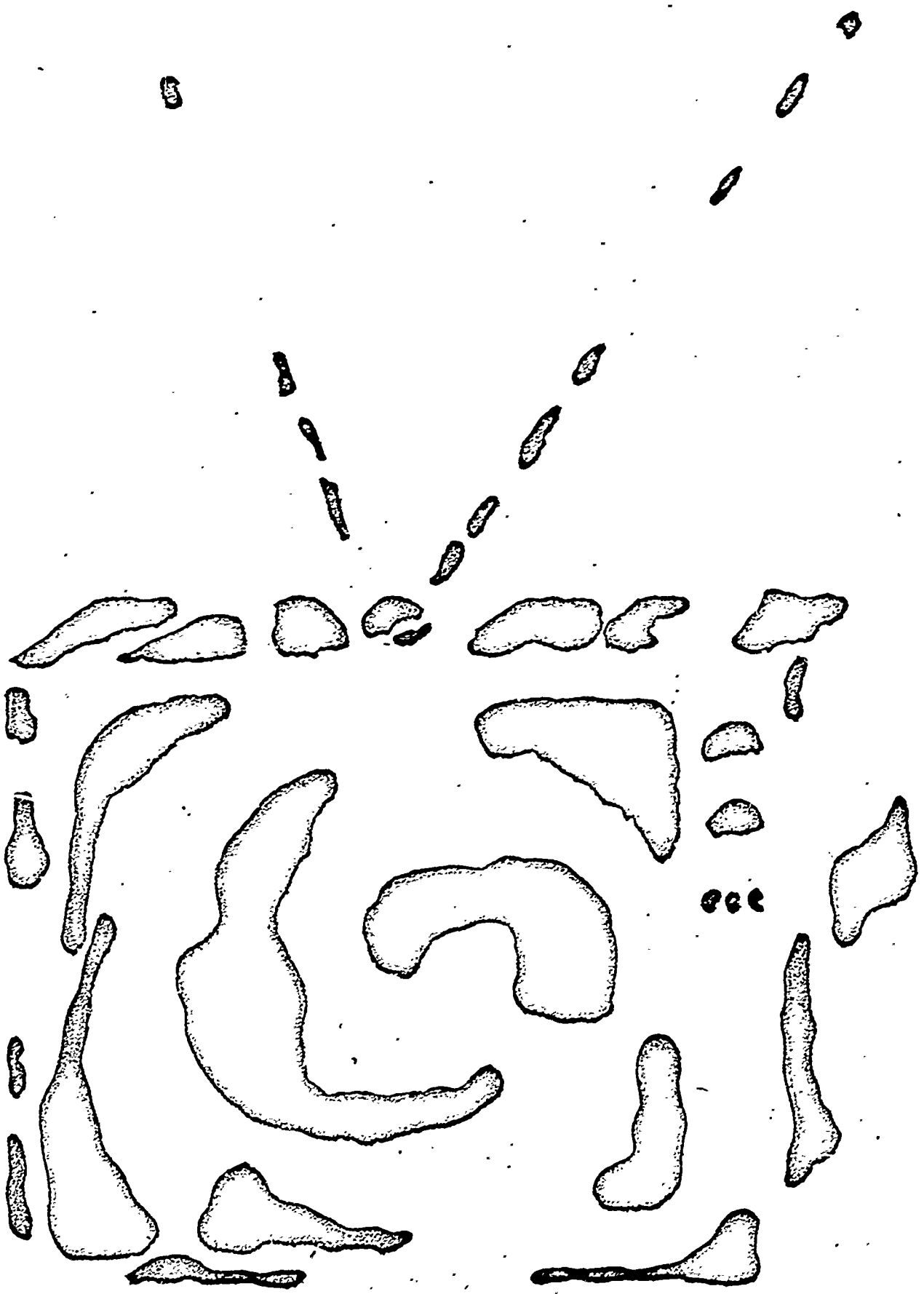
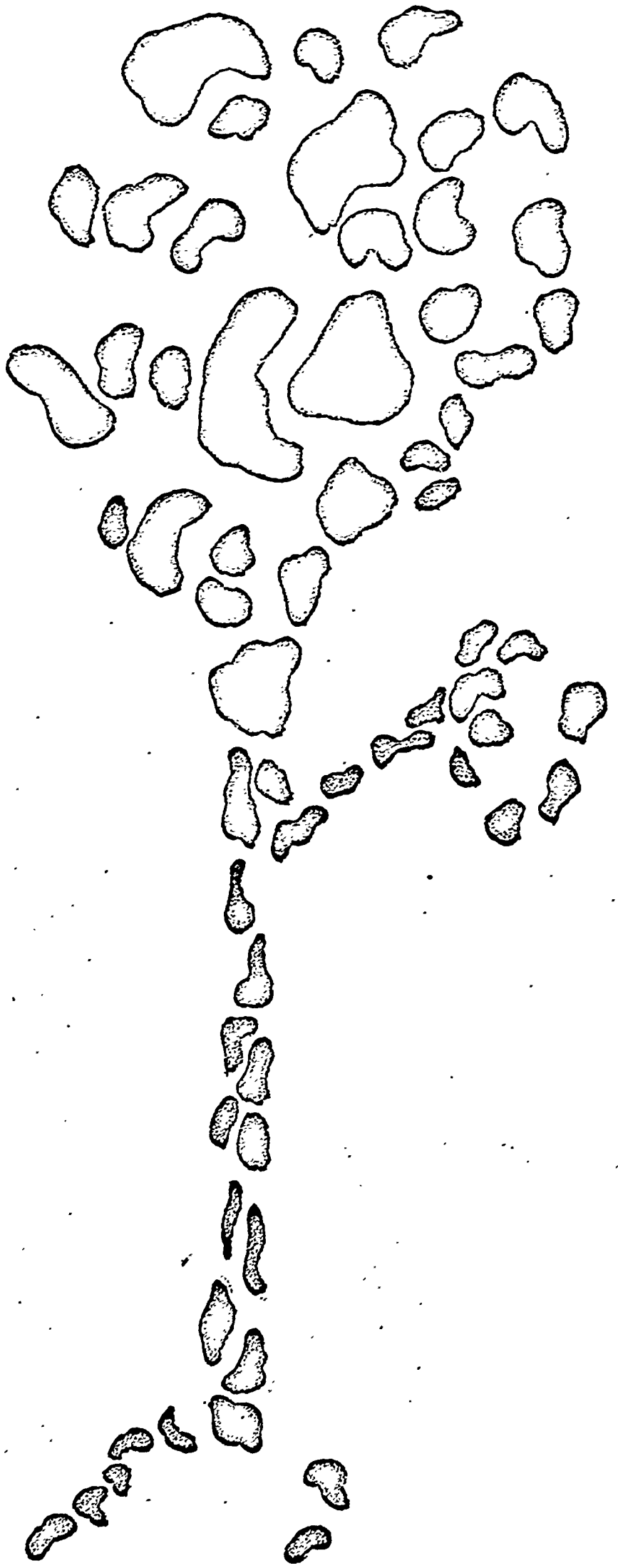
Appendix A. 1. Street-figure, chair.



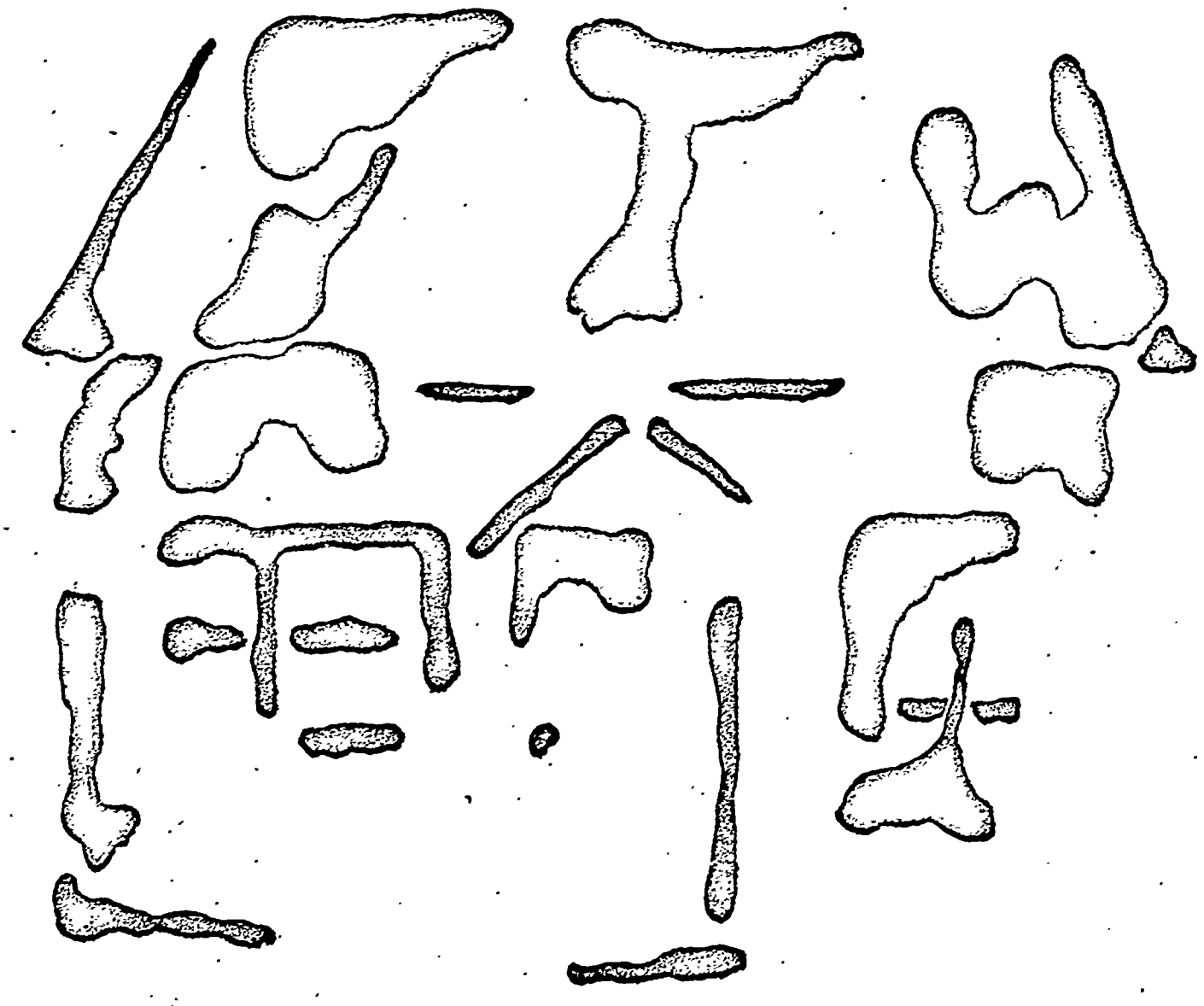
Appendix A. 2. Street-figure, T.V. set.



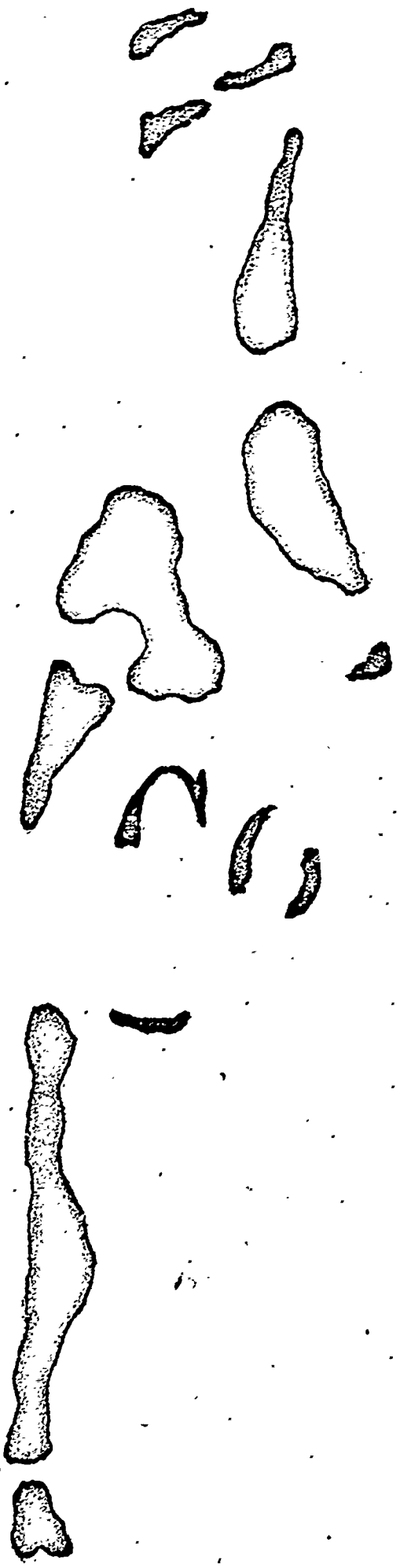
Appendix A. 3. Street-figure, tree.



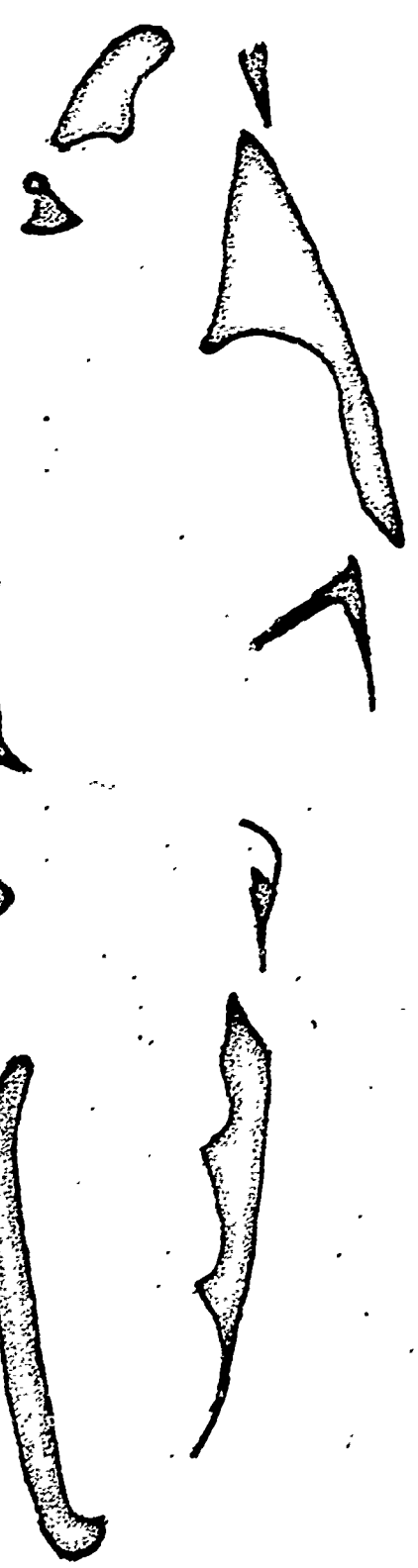
Appendix A. 4. Stree-figure, house.



Appendix A. 5. Stree-figure, Coke bottle.

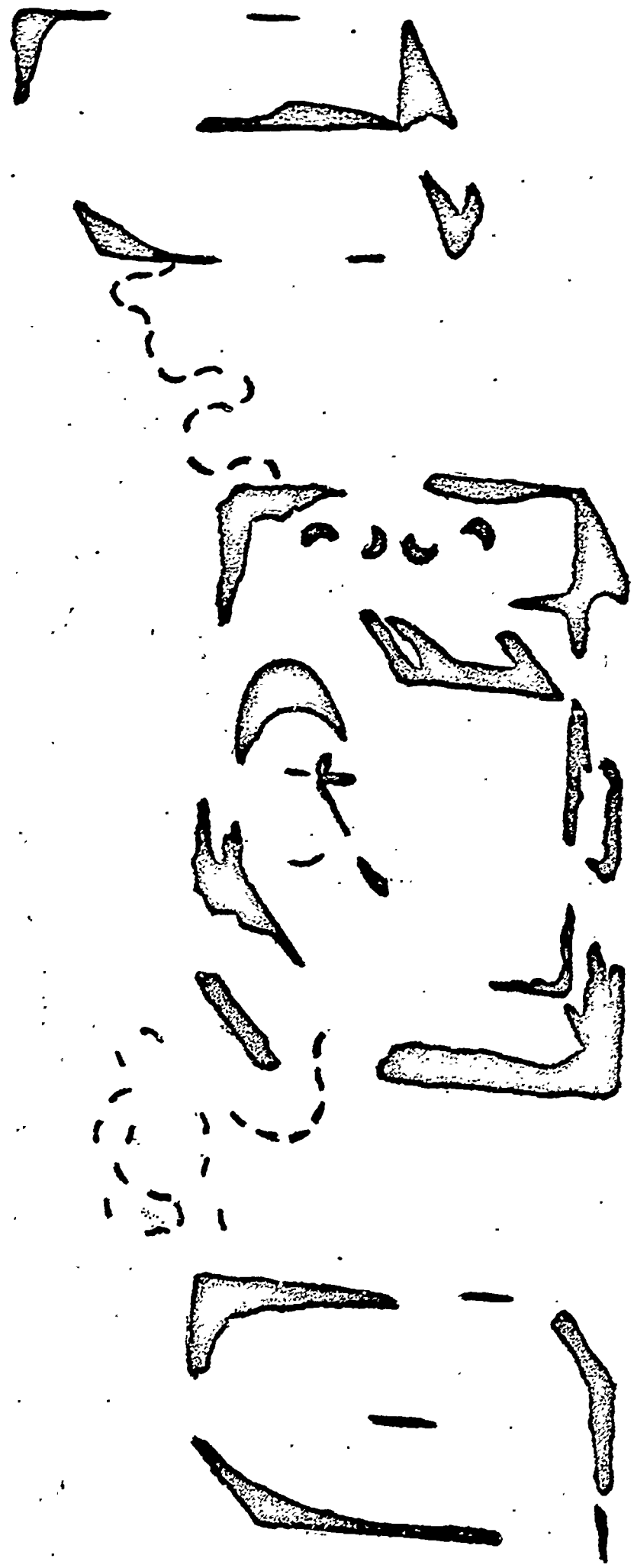


Appendix A. 6. Street-figure, sport car.

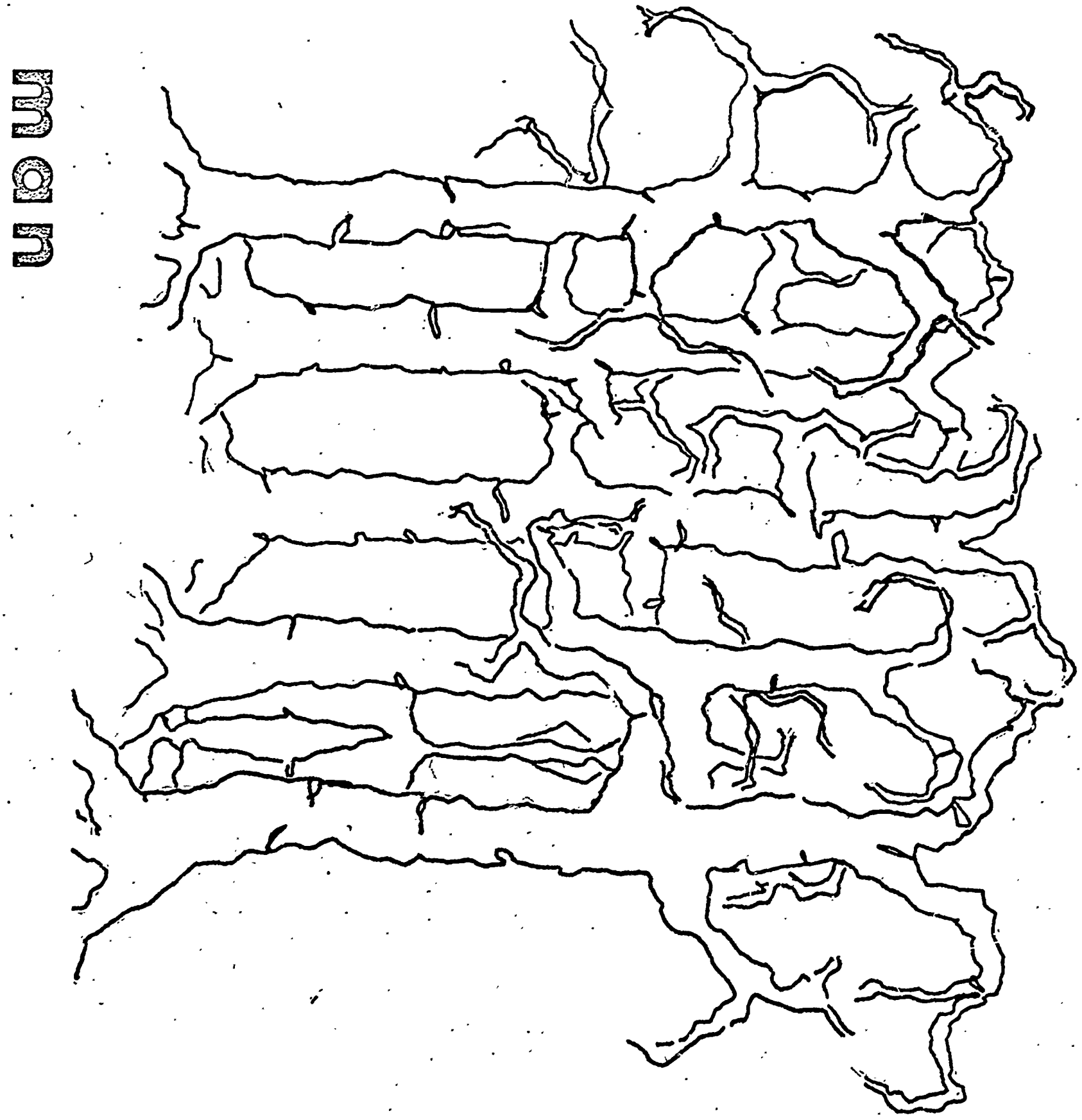


Appendix A. 7. Street-figure, horse.

Appendix A. 8. Stree-figure, stereo.

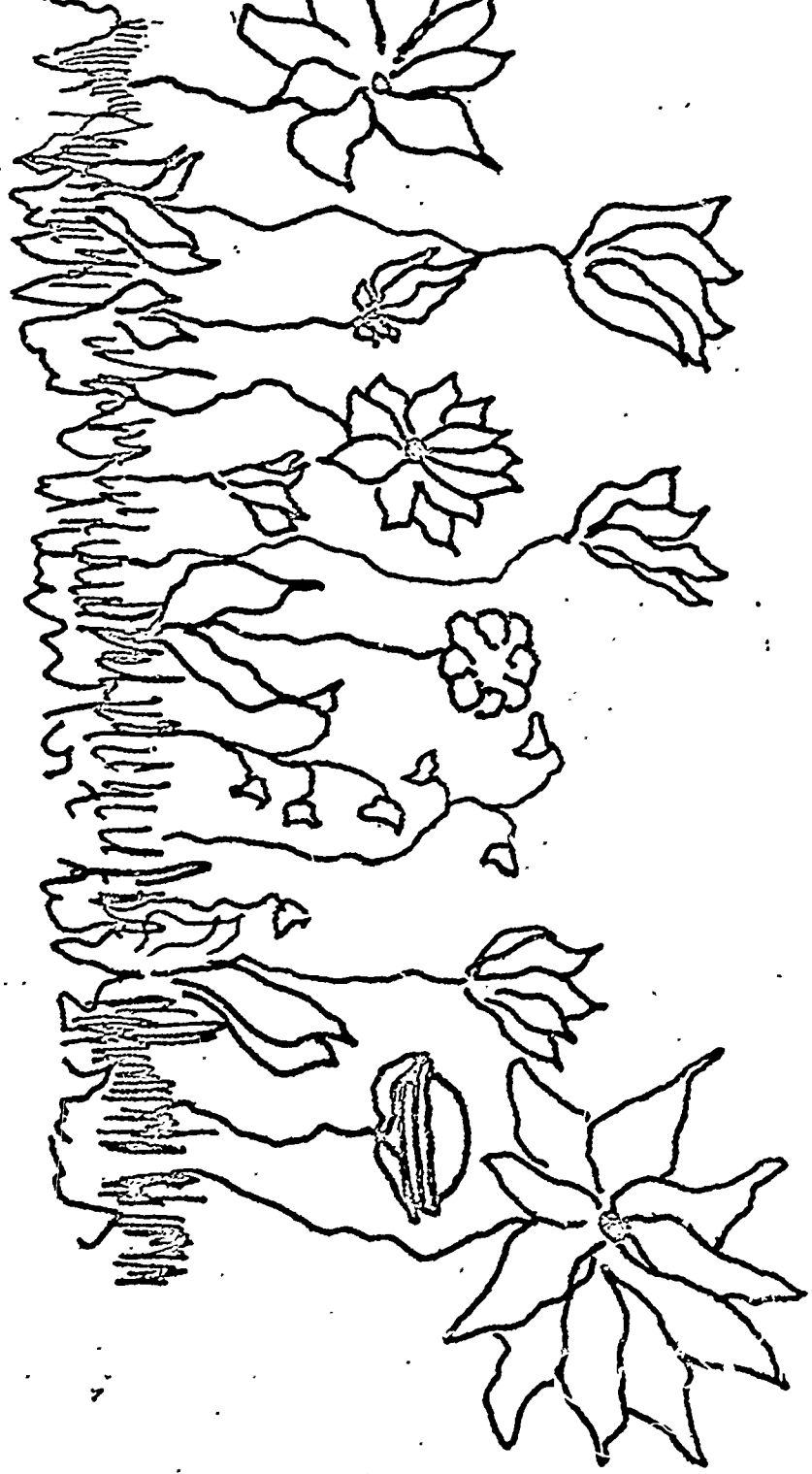


Appendix A. 9. Hidden-figure, man.



Appendix A. 10. Hidden-figure, hamburger.

hamburger



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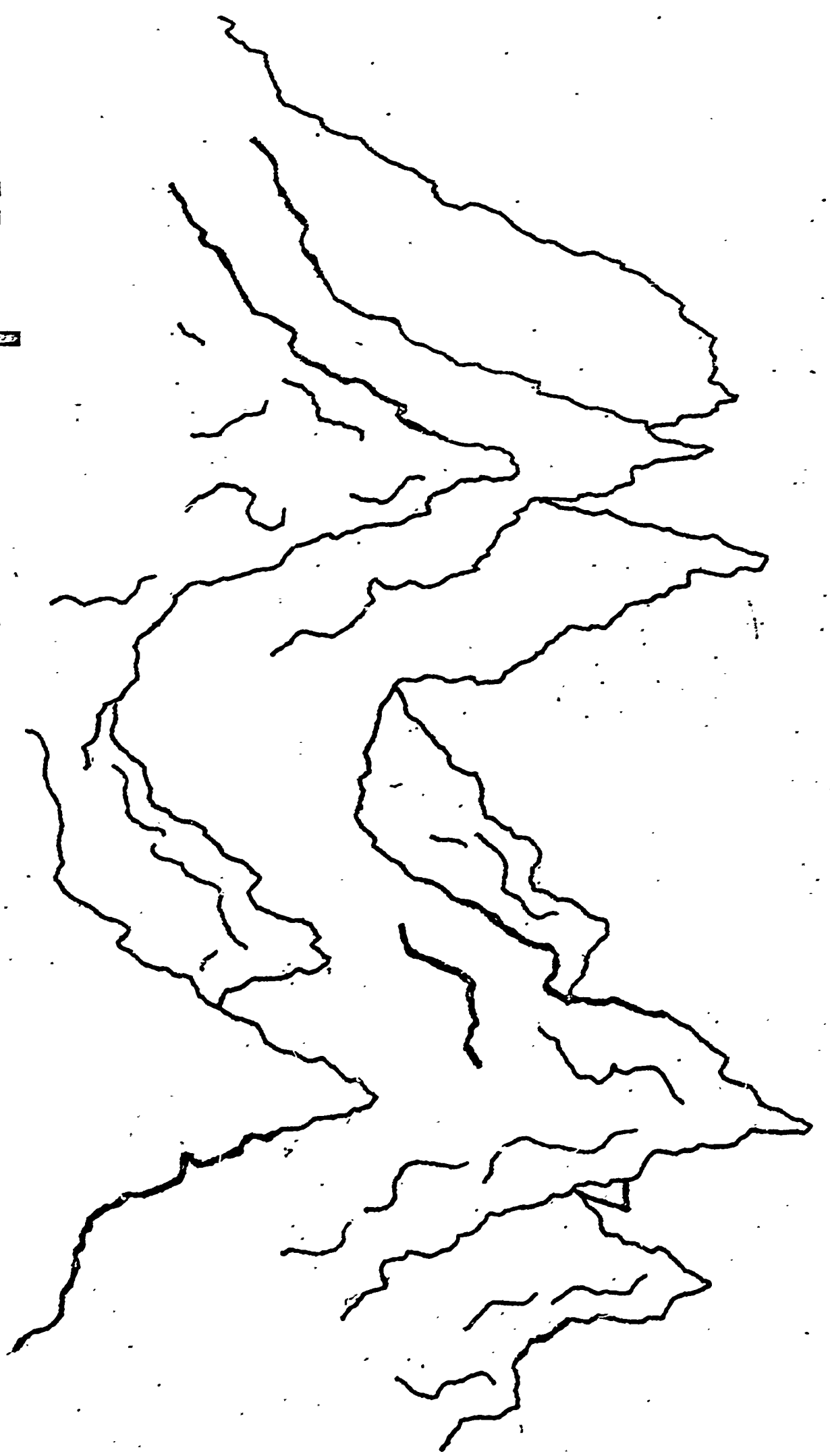
Appendix A. 11. Hidden-figure, number "7".



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